CoastWatch Software Library and Utilities: User's Guide

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U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL ENVIRONMENTAL SATELLITE, DATA, AND INFORMATION SERVICE
COASTWATCH PROGRAM

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Privacy Policy:

On startup, this software queries network servers for up-to-date version information, at which time data is collected and stored by the server automatically concerning the computer IP address, type of operating system, version of the software, and the date and time. This information does not identify you personally. It is used to help improve the software by providing usage statistics. More details on NOAA's privacy policy may be found at http://www.noaa.gov/privacy.html.

Obtaining a Copy:

To download a copy of the CoastWatch Utilities, visit:

http://coastwatch.noaa.gov/cw_cwfv3.html

For general information on CoastWatch products and services, visit:

http://coastwatch.noaa.gov

Providing Feedback:

Email questions, comments, suggestions, and bug reports to the CoastWatch help desk at `coastwatch.info@noaa.gov`. In order to receive help, the following information must be included in the email:

1. The version and operating system of the software used, for example *cwf-3.1.4 on Windows XP*.
2. The type of data file used and where the file was obtained, for example *CoastWatch .cwf files obtained from the SAA web site*. If the data origin is unknown, include some example data filenames.
3. If sending a bug report or asking for clarification, a description of how to reproduce your result:
   - For a command-line tool, a transcript of the terminal session during which the question or problem arose. The contents of the terminal session including the command used and its output may be cut and pasted directly into the email.
   - For a graphical interface tool, a step-by-step method to recreate where the question or problem arose. For example, *Open data file xxx, click this button, then that button.*

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Chapter 1

Introduction

The primary goal of the CoastWatch Utilities software is to aid data users in working with NOAA/NESDIS CoastWatch satellite data. Since CoastWatch data is distributed as individual files in a scientific data format that is not recognized by standard image viewers, the CoastWatch Utilities are useful for manipulating and creating images from CoastWatch data for both recreational and scientific applications. CoastWatch data files contain:

1. Global file attributes that describe the date/time and location of the Earth data in the file, as well as any relevant data processing details.
2. Earth data as a set of two-dimensional numerical arrays, each with a unique name. These *variables* hold the actual scientific data and accompanying attributes, such as scaling factor and units, that describe how to use the data values.

The CoastWatch Utilities allow users to selectively access and extract this information in a number of ways.

1.1 A Brief History

The CoastWatch Utilities have been evolving since 1998. The original utilities were capable of working with CoastWatch IMGMAP format data files, the standard data distribution format (limited to NOAA AVHRR data) for CoastWatch satellite data until 2003. The current utilities are capable of reading CoastWatch IMGMAP, NOAA 1b AVHRR, and CoastWatch HDF, a new format based on the NCSA Hierarchical Data Format (HDF) that has been adopted by CoastWatch for distributing Earth data from a host of different satellites and sensors. Following is a sketch of the software evolution:

- Version 1: 1997. The first version created CoastWatch IMGMAP files from TeraScan Data Format (TDF), a proprietary format from SeaSpace Corporation. It was never publicly released.
- Version 2: 1998-2000. The second version was released to the CoastWatch data user community and worked with CoastWatch IMGMAP (CWF) files only. Users could convert CWF files to other formats, create GIF images, perform land and cloud masking, create data composites, and other related tasks.

- Version 3: 2001-2006. The third version was released to have a more flexible data handling capability, with support for both CoastWatch IMGMAP and the new CoastWatch HDF format. The CoastWatch Data Analysis Tool (CDAT) was integrated into the package. Additional capabilities were added for NOAA 1b AVHRR, level 2 swath style data, automatic navigational correction, ESRI shapefiles, and other improvements.

1.2 Installation Notes

1.2.1 System Requirements

Operating system The CoastWatch Utilities are currently available for Windows, Linux, Solaris, MacOS X, and AIX only.

Java version As of version 3.2.1, the correct Java Runtime Environment (JRE) is packaged with the Windows, Linux, and Solaris versions of the CoastWatch Utilities. There is no need to install it separately – it will be placed in a subdirectory of the installation directory and will only be used by the CoastWatch Utilities. For Mac OS X and IBM AIX, a JRE version **1.5.0 or higher** is required on the machine:

- **Mac OS X:** Generally an up-to-date version of Mac OS X has the correct Java version. To check the current Java version, go to *Applications -> Utilities* in the Finder and start the Terminal. Type `java -version`, hit enter, and look at the first line of output. If the version does not start with 1.5.0 or greater, run *Software Update* from the Apple menu or visit `http://www.apple.com/java` to download manually.
- **IBM AIX:** To check the current Java version, run a terminal such as xterm and type `java -version`. If the JRE is in the path, the first line of output should start with 1.5.0 or greater. If not, visit `http://www.ibm.com/developerworks/java/jdk/aix` and click on the downloads link to get Java 1.5, sometimes also referred to as *Java 5*.

Disk space A minimum of 150 Mb is required for the installed software. It is recommended to have at least 300 Mb of space in total to allow for downloading and manipulating satellite datasets. More disk space may be required for larger datasets (the author routinely has 2 Gb of satellite data files on disk).

Memory A minimum of 128 Mb is required, while 256 Mb is recommended. More memory may be required depending on the number of concurrent processes running on the computer.

1.2.2 Downloading

To download, visit the CoastWatch central web site:

`http://coastwatch.noaa.gov/cw_cwfv3.html`

and download the package appropriate for your operating system. To install, read one of the following sections depending on your platform.

1.2.3 Installing on Windows

If upgrading to a new version, there is no need to uninstall the previous version – the new installation setup program will handle the details. To install the new version, simply double-click the downloaded installation package. The setup program will install the software in a user-specified directory, and add shortcuts to the Start Menu. The User's Guide shortcut (for this document) is also added to the Start Menu.

Advanced users of the command-line tools may want to add the installed executable directory to their path for easier command-line execution. To do this on Windows XP, go to the Windows *Start Menu* and click *Control Panel -> Performance and Maintenance -> System*, select the *Advanced* tab and click the *Environment Variables* button. Edit the entry for the *Path* variable under *System variables* and add the full path to the installed executable directory, for example `C:\Program Files\CoastWatch Utilities\bin`. Other Windows operating systems will have a similar procedure for adding a path.

1.2.4 Installing on Mac OS X

The Mac OS X installation package is a disk image (DMG) file that contains support for both PowerPC and Intel processors. Mac users should download the DMG file, double-click to mount it, and then double-click the installer program. When upgrading, the new version of the utilities will automatically uninstall the old version.

Advanced users of the command-line tools may want to add the installed executable directory to their path for easier command-line execution. In a Terminal session, add the following lines to the `.profile` file:

```
export PATH=${PATH}:"/Applications/CoastWatch Utilities/bin"
```

and then open a new Terminal window for the changes to take effect.

1.2.5 Installing on Unix

For Linux users who downloaded the Linux RPM file, run the normal RPM command as root:

```
rpm -Uvh filename
```

which will install or upgrade the software into `/opt/cwf` and place links to the executables into `/usr/local/bin`. For Unix users who downloaded the self-installing shell script, the package may be installed as a normal user or as root by executing the shell script and following the instructions in the graphical setup wizard. For Unix users who downloaded the tar archive file for a non-graphical install, extract the archive as follows:

```
gunzip filename
tar -xf filename
```

Unix users may also want to add the installed executable directory to their `$PATH` environment variable for easier command-line execution, for example:

`setenv PATH ${PATH}:/opt/cwf/bin` (in `.cshrc`)
`export PATH=${PATH}:/opt/cwf/bin` (in `.bashrc`)

1.3 Using the Software

The CoastWatch Utilities are made up of various individual tools. Graphical tools allow users a point-and-click interface for working with data interactively; they have a built-in help system with brief details on each key feature. To complement these, there are also command line tools that allow users to process data using a text-only command prompt or scripting language. Command line tools may be passed the --help option to obtain a short synopsis of parameters. A complete discussion on the command line parameters for both graphical and command line tools may be found in the manual pages of Appendix A.

Functionally, the CoastWatch Utilities are designed to meet the data processing and rendering needs of many different types of data users. The individual tools have been developed from both in-house requirements and data user suggestions. The functionality of the tools may be divided into several categories based on data processing task:

Information and Statistics File contents, statistics computations on variables (for example min, max, mean, standard deviation), direct access to raw file and variable attributes.

Data Processing Data format conversions, compositing, generic variable math, data sampling.

Graphics and Visualization Interactive visualization/analysis, batch image rendering, ancillary graphics creation such as data coverage maps, grids, coastlines, landmasks.

Registration and Navigation Resampling of data from one projection to another, interactive generation of region masters, manual and automatic navigational correction, computation of solar and Earth location angles.

Network Data download and server status.

1.4 Third Party Software

There are a number of other *generic* software packages than can be used to read data from CoastWatch HDF data files. They are *generic* in the sense that they can read the numerical and text data, but they cannot interpret the metadata conventions used by CoastWatch. They are well suited to advanced users who wish to have more detail on HDF data file contents. Users should always refer to the CoastWatch HDF metadata specification of Appendix B when using third party software with CoastWatch HDF files.

The National Center for Supercomputing Applications (NCSA) created HDF over 15 years ago, and is the main source of information on the HDF format specification and software libraries. Users can download tools for working with HDF from the main web site:

`http://hdf.ncsa.uiuc.edu`

Many of the tools are command line, but HDFView is a useful graphical tool.

Other non-NCSA software has been HDF-enabled by linking against the NCSA HDF libraries. Among those packages are IDL, Matlab, and OPeNDAP. A more complete list of non-NCSA software may be found at:

http://hdf.ncsa.uiuc.edu/tools.html

Chapter 2

Common Tasks

The first step in using the CoastWatch Utilities is discovering which tool should be used for the task at hand. To aid in this search, this section categorizes the tools by the most common tasks that data users perform. This section should be used as a guide to the functionality of the tools, while the referenced manual pages of Appendix A give complete details on each tool's behaviour and command line options.

2.1 Information and Statistics

The cwinfo tool lists data file contents, including various global file attributes and the full set of Earth data variables in the file. This tool is mainly useful because its output is human readable, as opposed to a raw data dump from a generic HDF tool. It also allows the user to display latitude and longitude data for the data corners and center point. The --verbose option to cwinfo shows the process of identifying the file format, for use during file format debugging or when a file is suspected to be corrupt.

The cwstats tool calculates statistics for each Earth data variable in the file: count, valid, minimum, maximum, mean, standard deviation. This is good for assessing the data quality and checking to see that the data values fall into the expected range. It is recommended that --sample 0.01 be used to sample only 1% of the data as this saves a large amount of I/O and computation time. The *count* is the total number of data values (rows $\times$ columns), while the *valid* value is the number of data values that were not just fill values. Generally, CoastWatch data files contain satellite data that does not always cover the full region of the file, since the satellite view may have clipped the edge of the region during overpass. In these cases, fill values are written for the missing data and the fill values are skipping during statistics computations. Fill values are also used to signify that data has been masked out for quality purposes (see the cwmath tool for an example of masking and section 2.2 for details on how masking can be used).

The hdatt tool is only useful for CoastWatch HDF files[1] and performs low-level reading and writing of HDF attribute data. This may be needed in a case where an attribute value has to be changed without rewriting the file, or some non-standard attribute data needs to be appended. The hdatt manual page

[1]The hdatt tool works with any HDF 4 file using the SDS interface, but the primary intent is for using it with CoastWatch HDF files. We say that it only works with CoastWatch HDF because it does not work with CoastWatch IMGMAP or any other non-HDF file format supported by the utilities.

gives many good examples of when it may be required to modify or create attributes.

2.2 Data Processing

The cwimport tool converts data into CoastWatch HDF format. Note that it is *not necessary* to convert all data into CoastWatch HDF before working with the data using the CoastWatch Utilities. In many cases, the same operations may be performed on the data in its native format, especially when the operation only reads information and performs no file modification. This is due to the design of the CoastWatch Utilities, which contains a software layer (call it the *Earth Data Reader* or *EDR* layer) separating the tools from the physical input file format. The cwexport tool complements cwimport – it converts data into various simple text or binary formats. The cwexport tool benefits from the EDR layer as well, and as such can convert data from CoastWatch HDF, CoastWatch IMGMAP, and NOAA 1b.

Often during satellite data processing, it is necessary to match data from the satellite sensor to data from in-situ measurements. The cwsample tool performs this function by taking as input a geographic latitude/longitude point or set of points and printing out the data values found at those points in the file.

Another common task in data processing is to combine data from one or more variables using a mathematical equation, or to combine data from multiple files in a data composite. The cwmath tool takes a math expression of the form $y = f(a, b, c, ...)$ where $a, b, c...$ are Earth data variables in the file, and loops over each pixel in the file to compute f. The cwcomposite tool combines data from one Earth data variable across multiple files by computing the mean, median, minimum, maximum, or latest value. The cwmath and cwcomposite tools may be used together to create composite charts of a given Earth variable; for example to create a weekly composite of sea-surface temperature (SST), mask out all cloud contaminated SST from each file using the cwmath *mask* function, and follow by running cwcomposite on all the masked SST files to compute the mean or median.

Certain data processing tasks are beyond the capabilities of the CoastWatch Utilities. In such a case, the recommended procedure is to access and process data using either the Java Language API outlined in chapter 4, or the native C HDF libraries from NCSA (see section 1.4). IDL and Matlab also have HDF access built in. The advantage of using the Java API provided by the CoastWatch Utilities is that most metadata reading tasks are already implemented.

2.3 Graphics and Visualization

The main interactive tool for displaying CoastWatch data files is the CoastWatch Data Analysis Tool (CDAT). The complexity of CDAT is such that it deserves its own section – see chapter 3 for a complete discussion of CDAT and its features. CDAT is mainly useful for creating one-off plots of CoastWatch data, performing data surveys, and drawing annotations on top of the data image. In contrast, the command line tools discussed in this section are designed for the automated creation of plots and graphics from CoastWatch data from a scripting language such as Unix shell, Perl, or Windows batch files.

The cwrender tool creates images from Earth data variables, using either a palette or three channel composite mode. Many rendering options are available including coast line, land mask, grid line,

topographic, and ESRI shapefile overlays, custom region enlargement, and units conversion. Output formats supported include PNG, JPEG, GIF, GeoTIFF, and PDF.

The cwcoverage tool may be used to create graphics for documentation or web pages that depict the physical area that a data file or group of files covers on the Earth. The output shows an orthographic map projection with the boundary of each data file traced onto the sphere and labelled. Along similar lines, the cwgraphics tool creates land, coast, and grid graphics for the region covered by a data file. The output of cwgraphics is inserted into the data file as an 8-bit data variable for later use by cwrender or alternatively to be exported via cwexport for use in custom rendering or masking routines.

2.4 Registration and Navigation

Earth data from two data files is said to be *in register* if every corresponding pair of pixels has the same Earth location. We use the term *registration* to refer to the process of resampling data to a *master* projection. Data that has first been registered to a master may then be intercompared or combined with other data registered to the same master. Standard CoastWatch map-projected data files that have been registered to the same master projection can be intercompared or combined on a pixel by pixel basis.

Users may create their own master projections and CoastWatch map-projected data files using the cwmaster and cwregister tools. The cwmaster tool is an interactive tool for designing master map projections. The tool allows users to create CoastWatch HDF masters that employ one of the various map projections supported by the General Cartographic Transformation Package (GCTP)[2], such as Mercator, Polar Stereographic, Orthographic, and many others. Once created, the master projections can be used in the cwregister tool to resample data to the new master projection.

When Earth image data is captured from a satellite and processed, there are cases in which inaccuracies in satellite position and attitude (roll, pitch, and yaw) cause coastlines to appear *shifted* with respect to the image data. We say that such data requires a *navigational correction*. Ideally the navigational correction should be applied to the satellite data while in the sensor projection before any registration to a map projection master. In reality data users often only have access to the final map-projected products. However, since these map-projected products generally cover a small geographic area, acceptable navigational corrections can often be achieved by applying an offset to the image data of a few pixels in the rows direction and a few pixels in the columns direction. To that end the cwnavigate and cwautonav tools are used to apply navigational corrections to CoastWatch data files. The cwnavigate tool applies a manual correction, normally derived from the user's own observation of the data or some preexisting database of corrections. The cwautonav tool attempts to derive and apply a correction automatically from the image data in the file.

A final tool related to registration/navigation is cwangles which computes explicit latitude, longitude, and solar angles based on metadata in the CoastWatch data file. Some data users appreciate having latitude and longitude values at each pixel rather than simply GCTP map projection parameters or swath polynomial coefficients. Such Earth location data is useful when exporting CoastWatch data for use in other software packages. Note that text output from the cwexport tool (see section 2.2) can also include the latitude and longitude of each pixel without having to run cwangles.

[2]See Appendix B for a discussion of CoastWatch HDF metadata which relies on GCTP for map projection parameters.

2.5 Network

The cwdownload tool has a command line only interface and is recommended for advanced data users only. The tool is used for retrieving recent data files from a CoastWatch data server, or maintaining an archive of certain data files of interest. For regular data file retrieval, the tool can be run via the Unix cron daemon or Windows Task Scheduler (located under System Tools in newer versions of Windows). Currently, only AVHRR data is handled by cwdownload. Data users should contact the CoastWatch Help Desk (see the About section on http://coastwatch.noaa.gov) for access to a CoastWatch data server to use with cwdownload.

The cwstatus tool shows a graphical view of the status of a CoastWatch data server, and is intended for use by CoastWatch staff only. The status tool displays the current list of satellite passes, their properties, and a graphical view of the pass footprint on the Earth along with a preview image.

Chapter 3

The CoastWatch Data Analysis Tool

Coming soon.

Chapter 4

Programmer's API

Coming soon.

Appendix A

Manual Pages

A.1 cdat

Name

cdat - performs visual Earth data analysis.

Synopsis

cdat [OPTIONS] input
cdat [OPTIONS]

Options:

-h, --help
-s, --splash

Description

The CoastWatch Data Analysis Tool (CDAT) allows users to view, survey, and save Earth datasets. Detailed help on the usage of CDAT is available from within the utility using the menu bar under *Help | Help and Support* .

Parameters

Main parameters:

input The input data file name. If specified, the data file is opened immediately after CDAT starts.

Options:

-h, --help Prints a brief help message.

-s, --splash Shows the splash window on startup. The splash window shows the version, author, and web site information.

Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.
- Invalid input file name.

Examples

The following shows the use of CDAT to view data from a CoastWatch IMGMAP file:

```
phollema@localhost:<~/cwatch/satdata/2002_319_2144_n16_wl> cdat
  2002_319_2144_n16_wl_c2.cwf
```

A.2 cwangles

Name

cwangles - computes Earth location and solar angles.

Synopsis

cwangles [OPTIONS] input

Options:

-f, --float
-h, --help
-l, --location
-s, --scale=FACTOR/OFFSET
-u, --units=TYPE
-v, --verbose
-z, --sunzenith

Description

The angles tool computes Earth location and solar angles for an Earth data file. Angles may be computed as scaled integer or floating point values, and in radians, degrees, or cosine. The Earth location values computed refer to the center of each pixel.

Parameters

Main parameters:

input The input data file name.

Options:

-f, --float Specifies that data should be stored as 32-bit floating point values with no scaling. The default is to store as 16-bit signed integers with a scaling factor of 0.01.

-h, --help Prints a brief help message.

-l, --location Specifies that Earth location latitude and longitude data should be computed.

-s, --scale=FACTOR/OFFSET The data scale factor and offset. Data values are scaled to integers using the factor and offset under the equation:

```
integer = value/factor + offset
```

The default factor is 0.01 and offset is 0. This option is ignored if **--float** is used.

-v, --verbose Turns verbose mode on. The current status of data computation is printed periodically. The default is to run quietly.

-u, --units=TYPE The units type. Valid units are 'deg' for degrees, 'rad' for radians, or 'cos' for cosine of the angle. The default is to compute angles in degrees.

-z, --sunzenith Specifies that solar zenith angle data should be computed.

Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.
- Invalid input file name.
- No angle computations specified.

Examples

The following shows the computation of latitude and longitude data for a CoastWatch HDF product file:

```
phollema@localhost:<~/cwatch/satdata/angles_test> cwangles
  --float --location 2002_361_1049_n16_ax.hdf

cwangles: Reading input 2002_361_1049_n16_ax.hdf
cwangles: Creating latitude variable
cwangles: Creating longitude variable
cwangles: Calculating angles
cwangles: Computing row 0
cwangles: Computing row 100
cwangles: Computing row 200
cwangles: Computing row 300
cwangles: Computing row 400
cwangles: Computing row 500
cwangles: Computing row 600
cwangles: Computing row 700
cwangles: Computing row 800
cwangles: Computing row 900
cwangles: Computing row 1000
```

Another example below shows the computation of solar zenith angle, stored as the cosine and scaled to integer data by 0.0001:

```
phollema@localhost:<~/cwatch/satdata/angles_test> cwangles -v
  --sunzenith --units cos --scale 0.0001/0 test_angles.hdf

cwangles: Reading input test_angles.hdf
cwangles: Creating sun_zenith variable
cwangles: Calculating angles
cwangles: Computing row 0
cwangles: Computing row 100
cwangles: Computing row 200
cwangles: Computing row 300
cwangles: Computing row 400
cwangles: Computing row 500
cwangles: Computing row 600
cwangles: Computing row 700
cwangles: Computing row 800
cwangles: Computing row 900
cwangles: Computing row 1000
cwangles: Computing row 1100
cwangles: Computing row 1200
```

A.3 cwautonav

Name

cwautonav - automatically determines a navigational correction based on Earth image data.

Synopsis

cwautonav [OPTIONS] locations-file variable input

Options:

-c, --correlation=FACTOR
-f, --fraction=FRACTION
-h, --help
-H, --height=PIXELS
-m, --match=PATTERN
-M, --minboxes=N
-s, --search=LEVEL
-S, --separation=DISTANCE
-t, --test
-v, --verbose
-w, --width=PIXELS

Description

The autonavigation tool automatically determines a navigational correction based on Earth image data. The algorithm is as follows:

- **Step 1** - The user supplies a number of boxes of coastal data to use for navigation. The boxes are specified by the latitude and longitude of each box center in a text file separate from the Earth data file. The box dimensions are controlled by command line options.
- **Step 2** - Each box is run through an offset estimation algorithm. The algorithm first attempts to separate the pixels within a given box into two classes: land and water. If the classes are sufficiently separable, an image correlation is run by "shifting" the image data around to find the maximum correlation between land/water classes and a precomputed land mask database.
- **Step 3** - All navigation boxes with successful offset estimates are used to compute the mean offset for the entire input file. All user-specified variables in the input file are then corrected with the mean offset.

Note that because of the autonavigation algorithm design, there are a number of **limitations** :

- **Coastline features** - The algorithm relies partly on the user being able to specify navigation boxes containing "wiggly" coastline features such as peninsulas and bays. A flat coastline can cause the algorithm to generate inaccurate offset estimates.
- **Distinct classes** - Image data in the navigation boxes must be separable into distinct land and water classes. If the image data contains cloud, or if the land and water pixels do not differ significantly (too similar in visible or thermal radiance), then the class separation step will fail for some boxes.
- **Large areas** - The mean offset generated from the set of successful offset estimates in Step 3 may not model the actual navigational correction for data files that cover a large physical area. If the offsets differ significantly for navigation boxes at a great distance from each other, then the user should treat a number of subsets of the data file separately.
- **Rotation or scaling** - An offset correction cannot model the actual navigational correction if the data requires a rotation or scale correction.

Note that satellite channel data or channel-derived variables should be corrected with navigation but GIS-derived variables such as coastline and lat/lon grid graphics should not be corrected. Applying a navigational correction simply establishes a mapping between desired and actual data coordinates -- it does not change the gridded data values themselves. Once a data file has been autonavigated successfully, other CoastWatch tools in this package will take the correction into account when reading the data.

See the **cwnavigate** tool in this package for details on how to set a navigational correction manually, or to reset the existing navigation.

Parameters

Main parameters:

locations-file The file name containing a list of navigation box centers. The file must be a text file containing center points as latitude / longitude pairs, one line per pair, with values separated by spaces or tabs. The points are specified in terms of Earth location latitude and longitude in the range [-90..90] and [-180..180].

variable The variable name to use for image data.

input The input data file name. The navigational corrections are applied to the input file in-situ. For CoastWatch HDF files, the corrections are applied to individual variables. For CoastWatch IMGMAP files, corrections are applied to the global attributes and the **--match** option has no effect. No other file formats are supported.

Options:

-c, --correlation=FACTOR The minimum allowed image versus land mask correlation factor in the range [0..1]. If the image data matches the precomputed land mask to within the specified correlation factor, the navigation is considered to be successful. The default correlation factor is 0.95. Caution should be used in lowering this value, as it has a significant impact on the quality of navigation results.

-f, --fraction=FRACTION The minimum allowed class fraction in the range [0..1]. The class fraction is the count of land or water pixels from the class separation stage, divided by the total number of pixels in the navigation box. If the fraction of either land or water pixels is too low, the image data is rejected. The default minimum fraction is 0.05.

-h, --help Prints a brief help message.

-H, --height=PIXELS The navigation box height. By default, each navigation box is 100 pixels in height.

-m, --match=PATTERN The variable name matching pattern. If specified, the pattern is used as a regular expression to match variable names. Only variables matching the pattern will have the navigational correction applied. By default, no pattern matching is performed and all variables are navigated.

-M, --minboxes=N The minimum number of successful navigation boxes needed to apply the navigational correction. The default is 2.

-s, --search=LEVEL The search level starting from 0. This option should only be used if the magnitude of the navigational correction is likely to be half or more the size of the navigation box, as it can significantly increase the algorithm running time. In these cases, the offset estimation can often fail because the image data is so far off the correct geographic features that the class separation and image correlation steps are meaningless. When this option is specified, an area of (n+1)^2 times the size of the navigation box is searched, where n is the search level. By default, only image data within the navigation box is used (n = 0).

-S, --separation=DISTANCE The minimum allowed class separation distance in standard deviation units. Typical values are in the range [1..4]. The greater the distance, the more distinct the land and water classes are. The default distance is 2.5.

-t, --test Turns on test mode. All operations that compute the navigational correction are performed, but no actual correction is applied to the input file. By default, test mode is off and the input file is modified if a correction can be computed.

-v, --verbose Turns verbose mode on. Details on offset estimation and navigational correction are printed. The default is to run with minimal messages.

-w, --width=PIXELS The navigation box width. By default, each navigation box is 100 pixels in width.

Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.
- Invalid input file name.
- Unsupported input file format.

Examples

The following example shows an automatic correction of an East Coast CWF (IMGMAP format) file containing AVHHR channel 2 data. A total of 3 navigation boxes are specified in a text file, and the size of each box set to 60 by 60 pixels. The output shows that 2 of the 3 boxes were successful and a final navigational correction of (rows, cols) = (-3, 1) was applied to the file.

```
phollema@damdog<~/cwatch/satdata/level3> cwautonav -v --width 60
  --height 60 navbox.txt avhrr_ch2 2004_064_1601_n17_er_c2.cwf
cwautonav: Reading input 2004_064_1601_n17_er_c2.cwf
cwautonav: Testing box at 37.0503 N, 76.2111 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 2.33
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 44.2783 N, 66.1377 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 3.436
class noaa.coastwatch.util.NavigationOffsetEstimator: Image correlation = 0.965 at
  offset = (-3, 1)
cwautonav: Box offset = (-3, 1)
cwautonav: Testing box at 45.1985 N, 65.9262 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 3.814
class noaa.coastwatch.util.NavigationOffsetEstimator: Image correlation = 0.987 at
  offset = (-3, 1)
cwautonav: Box offset = (-3, 1)
cwautonav: Mean offset = (-3, 1)
cwautonav: Applying navigational correction
```

The next example below shows the import and automatic correction of multiple CWF files from the Gulf of Mexico. The AVHRR channel 1, channel 2, SST, and cloud mask variables are first imported to an HDF file. The automatic correction then runs using only data from AVHRR channel 2 which provides high contrast between land and water during the day. The final correction is applied to all variables in the input file. This combination of import and autonavigation is a convenient way of correcting a set of older CWF data files all at once, using just data from AVHRR channel 2.

```
phollema@damdog<~/cwatch/satdata/level3> cwimport -v
  --match '(avhrr.*|sst|cloud)' 2004_313_1921_n16_mr*.cwf
  2004_313_1921_n16_mr.hdf
cwimport: Reading input 2004_313_1921_n16_mr_c1.cwf
cwimport: Creating output 2004_313_1921_n16_mr.hdf
cwimport: Converting file [1/4], 2004_313_1921_n16_mr_c1.cwf
cwimport: Writing avhrr_ch1
cwimport: Converting file [2/4], 2004_313_1921_n16_mr_c2.cwf
```

```
cwimport: Writing avhrr_ch2
cwimport: Converting file [3/4], 2004_313_1921_n16_mr_cm.cwf
cwimport: Writing cloud
cwimport: Converting file [4/4], 2004_313_1921_n16_mr_d7.cwf
cwimport: Writing sst

phollema@damdog<~/cwatch/satdata/level3> cwautonav -v --width 60
  --height 60 navbox2.txt avhrr_ch2 2004_313_1921_n16_mr.hdf
cwautonav: Reading input 2004_313_1921_n16_mr.hdf
cwautonav: Testing box at 26.7734 N, 82.1731 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 3.239
class noaa.coastwatch.util.NavigationOffsetEstimator: Image correlation = 0.945 at
  offset = (-2, 1)
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient correlation
cwautonav: Box failed
cwautonav: Testing box at 29.1666 N, 83.0324 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 3.54
class noaa.coastwatch.util.NavigationOffsetEstimator: Image correlation = 0.985 at
  offset = (-2, 1)
cwautonav: Box offset = (-2, 1)
cwautonav: Testing box at 29.9141 N, 84.3543 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 4.514
class noaa.coastwatch.util.NavigationOffsetEstimator: Image correlation = 0.976 at
  offset = (-2, 0)
cwautonav: Box offset = (-2, 0)
cwautonav: Testing box at 30.3258 N, 88.1352 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 3.006
class noaa.coastwatch.util.NavigationOffsetEstimator: Image correlation = 0.954 at
  offset = (-3, 0)
cwautonav: Box offset = (-3, 0)
cwautonav: Testing box at 27.8423 N, 82.5433 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 3.59
class noaa.coastwatch.util.NavigationOffsetEstimator: Image correlation = 0.953 at
  offset = (-2, 1)
cwautonav: Box offset = (-2, 1)
cwautonav: Mean offset = (-2.25, 0.5)
cwautonav: Applying navigational correction
```

Another example below shows the correction of a Hawaii AVHRR HDF file using many 15 by 15 pixel navigation boxes distributed throughout the islands. AVHRR channel 2 data is used to compute the optimal offset, and the final correction is applied only to AVHRR sensor bands and derived variables.

```
phollema@damdog<~/cwatch/satdata/level3> cwautonav -v
  --match '(avhrr.*|sst|cloud)' --width 15 --height 15
  navbox3.txt avhrr_ch2 2005_042_0051_n16_hr.hdf
cwautonav: Reading input 2005_042_0051_n16_hr.hdf
cwautonav: Testing box at 21.7885 N, 160.2259 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 1.537
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 21.9856 N, 160.0938 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 1.395
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 21.6033 N, 158.2847 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 1.562
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 21.7144 N, 157.9678 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 1.982
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 21.0961 N, 157.3207 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 1.517
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 21.2448 N, 157.2547 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 2.252
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 21.2076 N, 156.9774 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 3.236
class noaa.coastwatch.util.NavigationOffsetEstimator: Image correlation = 0.973 at
  offset = (-2, 0)
cwautonav: Box
  offset = (-2, 0)
cwautonav: Testing box at 21.1581 N, 156.7001 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 2.293
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 20.9225 N, 157.0698 W
```

```
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 1.448
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 20.7115 N, 156.9642 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 1.506
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 21.3067 N, 158.1130 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 1.601
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 21.3067 N, 157.6508 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 1.593
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 20.5374 N, 156.7001 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 5.142
class noaa.coastwatch.util.NavigationOffsetEstimator: Image correlation = 0.978 at
  offset = (-2, 0)
cwautonav: Box
  offset = (-2, 0)
cwautonav: Testing box at 20.5499 N, 156.5680 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 2.834
class noaa.coastwatch.util.NavigationOffsetEstimator: Image correlation = 0.947 at
  offset = (-2, -1)
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient correlation
cwautonav: Box failed
cwautonav: Testing box at 20.5996 N, 156.4360 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 2.285
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 20.8108 N, 156.5152 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 2.092
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 20.9349 N, 156.4756 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 3.629
class noaa.coastwatch.util.NavigationOffsetEstimator: Image correlation = 0.969 at
  offset = (-2, -1)
```

```
cwautonav: Box
  offset = (-2, -1)
cwautonav: Testing box at 20.8357 N, 156.1190 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 2.46
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 20.2635 N, 155.8813 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 2.522
class noaa.coastwatch.util.NavigationOffsetEstimator: Image correlation = 0.964 at
  offset = (-2, 0)
cwautonav: Box
  offset = (-2, 0)
cwautonav: Testing box at 19.5140 N, 154.7985 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 1.64
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 19.7392 N, 155.0230 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 1.833
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 19.7267 N, 155.1022 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 1.688
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 18.9119 N, 155.6965 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 1.378
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 19.8642 N, 155.9342 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 1.583
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 19.0375 N, 155.8813 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 1.638
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Testing box at 22.0349 N, 159.7901 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 1.919
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
```

```
cwautonav: Box failed
cwautonav: Testing box at 22.1826 N, 159.3279 W
class noaa.coastwatch.util.NavigationOffsetEstimator: Land/water class separation
  distance = 1.496
class noaa.coastwatch.util.NavigationOffsetEstimator: Insufficient separation
cwautonav: Box failed
cwautonav: Mean offset = (-2, -0.25)
cwautonav: Applying navigational correction
```

A.4 cwcomposite

Name

cwcomposite - combines a time series of Earth data.

Synopsis

cwcomposite [OPTIONS] input [input2 ...] output
cwcomposite [OPTIONS] {-i, --inputs=FILE} output

Options:

-c, --coherent=VARIABLE1[/VARIABLE2[...]]
-h, --help
-m, --match=PATTERN
-M, --method=TYPE
-p, --pedantic
-v, --verbose
-V, --valid=COUNT

Description

The composite tool combines a time series of Earth data. Data variables are combined on a pixel-by-pixel basis using one of several statistical or temporal methods: mean, median, minimum, maximum or latest. The input files must have matching Earth transforms but may have different dates. The composite tool may be used, for example, to combine a number of sea-surface-temperature datasets into one in order to obtain a mean SST for a certain region and help eliminate cloud. Another use is to combine datasets from different regions that are registered to the same Earth transform to create a mosaic. The output dataset is constructed using metadata from each input dataset so that it properly reflects the different input dataset dates and other metadata.

Parameters

Main parameters:

input [input2 ...] The input data file names. At least one input file is required, unless the **--inputs** option is used. If multiple files are specified, they must have matching Earth transforms.

-i, --inputs=FILE The file name containing a list of input data files. The file must be an ASCII text file containing input file names, one per line. If multiple files are listed, they must have matching Earth transforms. If the inputs file name is '-', input is read from standard input.

output The output data file name.

Options:

-c, --coherent=VARIABLE1[/VARIABLE2[...]]Turns on coherent mode (only valid with **--method latest**). In coherent mode, the output values for all variables at a given pixel location are guaranteed to originate from the same input file. The specified variable list is used to prioritize variables to check for a valid latest value. If there are no valid values for the first variable at a given location, then the next variable is checked and so on until the latest valid value is found. This mode is useful for when data variables and their respective quality flags should be kept together during a composite operation. Without this option, the 'latest' composite method may select the latest valid data value from one input file, and the latest valid quality flag from another input file for a given location.

-h, --help Prints a brief help message.

-m, --match=PATTERN The variable name matching pattern. If specified, the pattern is used as a regular expression to match variable names. Only variables matching the pattern will be present in the output. By default, no pattern matching is performed and all variables are combined.

-M, --method=TYPE The composite method. Valid methods are 'mean', 'median', 'min', 'max', and 'latest'. The default is to calculate the mean.

-p, --pedantic Turns pedantic mode on. In pedantic mode, metadata from each input file is combined exactly such that composite attributes in the output file may contain repeated values. When pedantic mode is off, composite attributes are collapsed so that only unique values appear. By default, pedantic mode is off.

-v, --verbose Turns verbose mode on. The current status of data combination is printed periodically. The default is to run quietly.

-V, --valid=COUNT The minimum number of valid values required to form an aggregate function. By default, only one value per pixel is required. If the actual number of valid values is below this threshold, the output value is set to invalid.

Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.
- Invalid input or output file names.
- Unsupported input file format.
- Input file Earth transforms do not match.
- No matching variables found.
- Unsupported composite method.

Examples

The following shows the combination of several Earth datasets into one using the 'latest' composite method:

```
 phollema@localhost:<~/cwatch/satdata/hdf> cwcomposite -v
   --method latest 2003_097_1428_n17_wi_na.hdf
   2003_097_1607_n17_wi_na.hdf 2003_097_1751_n17_mo_na.hdf
   2003_097_1931_n17_mo_na.hdf 2003_097_n17_na.hdf

cwcomposite: Reading input 2003_097_1428_n17_wi_na.hdf
cwcomposite: Adding avhrr_ch1 to composite variables
cwcomposite: Adding avhrr_ch2 to composite variables
cwcomposite: Adding avhrr_ch4 to composite variables
cwcomposite: Reading input 2003_097_1607_n17_wi_na.hdf
cwcomposite: Reading input 2003_097_1751_n17_mo_na.hdf
cwcomposite: Reading input 2003_097_1931_n17_mo_na.hdf
cwcomposite: Creating output 2003_097_n17_na.hdf
cwcomposite: Writing avhrr_ch1
cwcomposite: Writing avhrr_ch2
cwcomposite: Writing avhrr_ch4
```

A.5 cwcoverage

Name

cwcoverage - creates an Earth data coverage map.

Synopsis

cwcoverage [OPTIONS] input1 [input2 ...] output
cwcoverage [OPTIONS] output

General options:

-h, --help
-v, --verbose

Output content and format options:

-a, --noantialias
-b, --background=COLOR
-c, --center=LATITUDE/LONGITUDE
-f, --foreground=COLOR
-s, --size=PIXELS

Dataset boundary options:

-H, --highlight=PATTERN
-l, --labels=LABEL1/LABEL2/...
-m, --map=OUTPUT
-x, --box=COLOR

Ground station options:

-C, --stationcolor=COLOR
-e, --elevation=DEGREES
-E, --height=KILOMETERS
-L, --stationlabels=LABEL1/LABEL2/...
-S, --stations=LAT1/LON1/LAT2/LON2/...

Description

The coverage tool creates an Earth data coverage map by accessing a number of user-specified Earth data sets and tracing the boundaries onto an orthographic map projection. The map is output as a PNG graphics file. Approximate satellite ground station coverage boundaries may also be added to the map.

Parameters

Main parameters:

input1 [input2 ...] The input data files name(s). If none are specified, the output PNG image contains only map graphics and possibly ground station circles (see the **--stations** option).

output The output PNG file name.

General options:

-h, --help Prints a brief help message.

-v, --verbose Turns verbose mode on. The current status of data rendering is printed periodically. The default is to run quietly.

Output content and format options:

-a, --noantialias Turns off line antialiasing. By default, the edges of lines are smoothed using shades of the drawing color. The use of this option can significantly reduce the size of the output file, while sacrificing visual quality.

-b, --background=COLOR The map background color. The color is specified by name or hexadecimal value. The default is black.

-c, --center=LATITUDE/LONGITUDE The map center location. By default, the center location is determined from the data sets.

-f, --foreground=COLOR The map foreground color. The color is specified by name or hexadecimal value. The default is a gray of 63% RGB intensity.

-s, --size=PIXELS The coverage map size in pixels. By default, the map size is 512 pixels.

Dataset boundary options:

-H, --highlight=PATTERN The highlighted input file matching pattern. By default, all input files are highlighted with the box boundary fill and color. With this option, only input files whose names match the pattern are highlighted. The remaining non-matching input file boundaries are drawn using the foreground color.

-l, --labels=LABEL1/LABEL2/... The labels for each input file. Labels are drawn at the center point of each dataset boundary. By default, no labels are drawn.

-m, –map=OUTPUT The output file for HTML image map output. The output file contains an HTML fragment with an image map and area polygons for each input file, similar to the following:

```
<map name="coverage_map">
  <area shape="poly" id="region_0" coords="111,64,170,63,179,132,108,134,111,64" />
  <area shape="poly" id="region_1" coords="75,106,132,109,133,179,66,174,75,106" />
  <area shape="poly" id="region_2" coords="121,124,183,121,192,188,119,191,121,124" />
</map>
```

The map may be used in an HTML document in conjunction with the output PNG coverage image to provide users with a clickable interface for area of interest selection.

-x, --box=COLOR The box boundary and fill color. The color is specified by name or hexadecimal value. The default is a color close to cyan.

Ground station options:

-C, --stationcolor=COLOR The ground station circle color. This option is only used in conjunction with the **--stations** option. By default, the box color is used (see the **--box** option).

-e, --elevation=DEGREES The minimum elevation of the ground station antenna above the horizon in degrees. This option is only used in conjunction with the **--stations** option. By default, the antenna elevation is set to 5 degrees, which approximates a NOAA HRPT tracking station with a 1.7 m diameter dish.

-E, --height=KILOMETERS The orbital height of the theoretical satellite above the Earth surface in kilometers. This option is only used in conjunction with the **--stations** option. By default, the satellite orbital height is set to 846.5 km which approximates a NOAA polar orbiter.

-L, --stationlabels=LABEL1/LABEL2/... The ground station labels. This option is only used in conjunction with the **--stations** option. When specified, each ground station location is labelled with its corresponding label. By default, no labels are drawn.

-S, --stations=LAT1/LON1/LAT2/LON2/... A list of ground station locations. For each ground station, a circle is drawn on the Earth, centered at the ground station. The circle shows the approximate area that a theoretical satellite can view from orbit while in sight of the station, ie: the ground station's real-time coverage area. See the **--height** and **--elevation** options to control the orbital parameters of the theoretical satellite. Note that the swath width of the satellite sensor is not taken into account in drawing the circle, so the area should be used as a conservative estimate of satellite coverage.

Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.

- Unrecognized color name.
- Invalid map center or station location.
- Mismatch between label and file or station count.

Examples

As an example, the following command shows the creation of a coverage plot of the ER and SR CoastWatch regions covering the US East coast:

```
phollema@damdog<~/cwatch/satdata/hdf> cwcoverage -v --labels ER/SR
  2004_155_1147_n15_er.hdf 2004_155_1147_n15_sr.hdf east_coast.png

cwcoverage: Reading input 2004_155_1147_n15_er.hdf
cwcoverage: Reading input 2004_155_1147_n15_sr.hdf
cwcoverage: Writing east_coast.png
```

A.6 cwdownload

Name

cwdownload - downloads data from a CoastWatch server.

Synopsis

cwdownload [OPTIONS] host

Options:

-a, --age=HOURS
-C, --coverage=PERCENT
-d, --dir=PATH
-f, --force
-h, --help
-p, --projection=TYPE
-r, --region=PATTERN
-s, --satellite=PATTERN
-S, --scenetime=PATTERN
-c, --script=PATH
-G, --station=PATTERN
-t, --test
-T, --timeout=SECONDS

Description

The download tool retrieves a set of user-specified data files from a CoastWatch data server. Data files may be selected based on satellite, scene time, region, ground station, and other parameters. Without any command line options, all data files on the server are retrieved. The command line options are used to filter the list of data files. Multiple options are used in conjunction, for example if both **--satellite** and **--scenetime** are specified, only files matching the specified satellites and scene times will be retrieved. The download tool has a built-in facility for avoiding redundant file downloads. Unless the **--force** option is used, files are only downloaded if no file with the same name already exists in the local directory. The **--test** option may be used for testing file download options without downloading any actual data.

Parameters

Main parameters:

host The CoastWatch server host name. There is no default host name.

Options:

-a, --age=HOURS The maximum age of the data in hours. Datasets contain a time stamp for the date and time that the data was taken by the sensor. Only datasets created more recently than the specified number of hours ago are retrieved, based on the clock on the host computer running the download. The default is to download regardless of date and time.

-C, --coverage=PERCENT The minimum data coverage in percent. Mapped regions may have less than 100% coverage when the edge of the satellite pass intersects the region area. The default minimum coverage is 0. The use of this option implies **--projection mapped** .

-d, --dir=PATH The download directory path. The default is to download to the current directory.

-f, --force Turns on forced mode. When forced mode is in effect, no check is performed to determine if the file already exists in the download directory. The default is to check if a file of the same name exists, and if so skip the download for that particular file.

-h, --help Prints a brief help message.

-p, --projection=TYPE The data projection type. Valid values are 'mapped' and 'swath'. Mapped datasets are those that have possibly been reduced in resolution, and registered to a standard map projection. Swath datasets are generally at the full sensor resolution and unregistered sensor scan projection. By default, all types of datasets are downloaded.

-r, --region=PATTERN The region code matching pattern. Multiple regions may be specified with a regular expression, for example '(er|sr|gr)' for the 'er', 'sr', and 'gr' regions. The default is to download all regions. The use of this option implies **--projection mapped** .

-s, --satellite=PATTERN The satellite name matching pattern. For example, 'noaa-16'. Multiple satellites may be specified with a regular expression, for example 'noaa-1[56]' for NOAA-15 and NOAA-16. The default is to download data from all satellites.

-S, --scenetime=PATTERN The scene time matching pattern. Valid times are 'day', 'night', and 'day/night'. Multiple times may be specified with a regular expression, for example '(day|night)' for day and night. The default is to download all scene times.

-c, --script=PATH ADVANCED USERS ONLY. The query script path. The default is /ctera/query.cgi.

-G, --station=PATTERN The ground station matching pattern. Multiple ground stations may be specified with a regular expression, for example '(wi|mo|hi)' for the wi, mo, and hi stations. The default is to download all ground stations.

-t, --test Turns on test mode. When the test mode is in effect, the data files are selected based on the specified command line parameters but no actual data is downloaded. The default is to perform the data download. Test mode may be used to determine if a certain set of command line parameters have the desired effect without having to wait for data files to transfer.

-T, --timeout=SECONDS The network timeout in seconds. If the network becomes unresponsive for the timeout period, the download is aborted. If there is a file currently in the process of downloading when the timeout occurs, the partial file is deleted. The default timeout is 30 seconds.

Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.
- Cannot contact data server.
- Invalid or write-protected download directory.
- Error transferring data file.

Examples

The following shows a download command that retrieves any NOAA-16 daytime data files for the East Coast north and south regions captured at Wallops Island to the /cwatch/satdata directory from the fictitious server foobar.noaa.gov:

```
phollema@localhost:<~> cwdownload --satellite noaa-16 --scenetime day
  --region '(er|sr)' --station wi --dir ~/cwatch/satdata foobar.noaa.gov

cwdownload: Contacting foobar.noaa.gov
cwdownload: Retrieving 2002_197_1719_n16_er.hdf
cwdownload: Retrieving 2002_197_1719_n16_sr.hdf
cwdownload: Retrieving 2002_197_1900_n16_er.hdf
cwdownload: Retrieving 2002_197_1900_n16_sr.hdf
cwdownload: Transferred 31715 kb in 4 files
```

A.7 cwexport

Name

cwexport - translates Earth data into external file formats.

Synopsis

cwexport [OPTIONS] input output

General options:

-f, --format=TYPE
-h, --help
-H, --header
-m, --match=PATTERN
-M, --missing=VALUE
-v, --verbose

Binary raster specific options:

-c, --scale=FACTOR/OFFSET
-o, --byteorder=ORDER
-r, --range=MIN/MAX
-s, --size=TYPE

ASCII text specific options:

-d, --dec=DECIMALS
-D, --delimit=STRING
-n, --nocoords
-R, --reverse

Description

The export tool translates Earth data into external formats as described below. In all cases, 2D data sets are exported in row major order starting from row 0. For example, if the Earth data values form the 2D array:

```
0 1 2 3
```

```
 4  5  6  7
 8  9 10 11
12 13 14 15
```

then values are output in the order:

```
0 1 2 3 4 5 6 7 ...
```

In the general case, multiple variables may be exported to the same data file. The use of the **--match** option may be used to select a specific variable or subset of variables.

Binary raster:

The output is a stream of binary data values – either 8-bit unsigned bytes, 16-bit signed integers, or 32-bit IEEE floating point values. For 8- and 16-bit output, data values may be scaled to integers using a minimum and maximum or by using a scaling factor and offset. For minimum/maximum scaling, integer data is calculated from data values using the equation:

```
integer = type_min + type_range*((value - min) / (max - min))
```

where type_min is 0 for 8-bit and -32768 for 16-bit, and type_range is 255 for 8-bit and 65535 for 16-bit. For scaling factor and offset, the following equation is used:

```
integer = value/factor + offset
```

In both cases, the results are rounded to the nearest integer and out of range values are assigned the missing value.

ASCII text:

The output is an ASCII text file with latitude, longitude, and data value printed -- one data value per line.

ArcGIS binary grid:

The output is a stream of 32-bit IEEE floating point values, ready for input to ArcGIS applications as a binary grid file. A header file may also be created to specify the Earth location and other parameters. In the case of the ArcGIS format, only one variable is allowed per binary grid file. If an attempt to export multiple variables is made, only the first variable is actually written.

Parameters

Main parameters:

input The input data file name.

output The output data file name. Unless the **--format** option is used, the output file extension indicates the desired output format: '.raw' for binary, '.txt' for text, and '.flt' for ArcGIS.

General options:

-f, --format=TYPE The output format. The current formats are 'bin' for binary raster, 'text' for ASCII text, 'arc' for ArcGIS binary grid, or 'auto' to detect the format from the output file name. The default is 'auto'.

-h, --help Prints a brief help message.

-H, --header Specifies that a header should be written with the output data. The header is written before any data and is different depending on the output format:

- Binary: The header consists of one byte specifying the number of dimensions followed by a series of 32-bit signed integers specifying the dimension lengths.
- Text: The header is one line consisting of an integer specifying the number of dimensions followed by a series of integers specifying the dimension lengths.
- ArcGIS: The header is a separate file used by ArcGIS applications to determine the dimensions of the data, the geographic position and resolution, and other parameters. The header file name is created by replacing any '.' followed by an extension in the output file name with '.hdr'

By default no header is written.

-m, --match=PATTERN The variable name matching pattern. If specified, the pattern is used as a regular expression to match variable names. Only variables matching the pattern will be exported. By default, no pattern matching is performed and all variables are exported.

-M, --missing=VALUE The output value for missing or out of range data. The default missing value is different depending on the output format:

- Binary: The default is 0 for 8-bit unsigned bytes, -32768 for 16-bit signed integers, and the IEEE NaN value for floating point.
- Text: The default is to print 'NaN' for missing values.
- ArcGIS: The missing value is fixed at -3.4e38 and the **--missing** option is ignored.

-v, --verbose Turns verbose mode on. The current status of data conversion is printed periodically. The default is to run quietly.

Binary raster specific options:

-c, --scale=FACTOR/OFFSET The data scale factor and offset. Data values are scaled to integers using the factor and offset (see the equation above). The default factor is 1 and offset is 0.

-o, --byteorder=ORDER The output byte order. Valid choices are 'host' for the host byte order, 'msb' for most significant byte first, or 'lsb' for least significant byte first. The default is the host byte order.

-r, --range=MIN/MAX The data scaling range. Data values are mapped to integers using the minimum and maximum values (see the equation above). There is no default range.

-s, --size=TYPE The binary value size. Valid choices are 'byte' for 8-bit unsigned bytes, 'short' for 16-bit signed integers, or 'float' for 32-bit IEEE floating point values. The default is 32-bit floats.

ASCII text specific options:

-d, --dec=DECIMALS The number of decimal places for printed geographic coordinate values. The default is 6 decimals.

-D, --delimit=STRING The value delimiter string. By default, values are separated with a single space character.

-n, --nocoords Turns geographic coordinate printing off. By default, each line has the form 'latitude longitude value' but with no coordinates, each line simply contains the data value.

-R, --reverse Specifies that coordinates should be printed in reverse order, 'longitude latitude'. The default is 'latitude longitude'.

Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.
- Invalid input or output file names.
- Invalid variable name.
- Unrecognized format, size, or byte order.

Examples

The following shows the export of AVHRR channel 1 data from a CoastWatch HDF file with the default 32-bit IEEE floating point value format, host byte order, no header, in verbose mode:

```
phollema@localhost:<~/cwatch/satdata> cwexport --verbose
  --match 'avhrr_ch1' 2002_216_1853_n16_gr.hdf 2002_216_1853_n16_gr.ch1

cwexport: writing 'avhrr_ch1'
```

Another example below shows the export of AVHRR channels 1, 2, and 4 to the same output file from a CoastWatch HDF file using 8-bit unsigned byte format, no header, in verbose mode. Range scaling is used to scale all values between -30 and 30 prior to conversion to byte values in the range 0 to 255. Note that some values may fall outside the range and be clipped, especially albedo values which can range up to 100. The clipped values are assigned the default missing value, which for byte data is 0.

```
phollema@localhost:<~/cwatch/satdata> cwexport --verbose
  --match 'avhrr_ch[124]' --size byte --range -30/30
  2002_216_1853_n16_gr.hdf 2002_216_1853_n16_gr.ch124

cwexport: writing 'avhrr_ch1'
cwexport: writing 'avhrr_ch2'
cwexport: writing 'avhrr_ch4'
```

A further example shows the export of AVHRR channel 4 data to an ASCII text file from a CoastWatch IMGMAP file in verbose mode. The geographic coordinates are printed in the order longitude, latitude, and delimited with a comma character. Any missing values are denoted with the value -999. A one line dimension header is prepended to the dataset.

```
phollema@localhost:<~/cwatch/satdata> cwexport --verbose
  --match 'avhrr_ch4' --format text --reverse --delimit ','
  --missing -999 --header 2002_214_2057_n16_wv_c4.cwf
  2002_214_2057_n16_wv_c4.txt

cwexport: writing 'avhrr_ch4'
```

The first few lines of the resulting text file are as follows:

```
2,512,512
-127.777901,51.212974,13
-127.768008,51.212974,13.75
-127.758116,51.212974,13.75
-127.748224,51.212974,13.1
-127.738332,51.212974,13.1
-127.728439,51.212974,13
-127.718547,51.212974,8.95
```

```
-127.708655,51.212974,7.45
-127.698763,51.212974,7.45
```

A final example below shows the export of AVHRR channel 2 data to an ArcGIS binary grid file from a CoastWatch IMGMAP file, verbose mode on. The binary grid data is written to a '.flt' file and the header data to a '.hdr' file.

```
phollema@localhost:<~/cwatch/satdata> cwexport --verbose
  --format arc --match 'avhrr_ch2' --header
  2002_214_2057_n16_wv_c2.cwf 2002_214_2057_n16_wv_c2.flt

cwexport: writing 'avhrr_ch2'
```

The header file contents are as follows:

```
nrows 512
ncols 512
xllcorner -14208797.57
yllcorner 6088966.68
cellsize 1099.96
nodata_value 1.4E-45
byteorder MSBFIRST
```

A.8 cwgraphics

Name

cwgraphics - creates Earth data annotation graphics.

Synopsis

cwgraphics [OPTIONS] input
cwgraphics [OPTIONS] input output

Options:

-c, --coast=PLANE
-g, --grid=PLANE
-h, --help
-l, --land=PLANE
-p, --political=PLANE
-v, --verbose
-V, --variable=NAME

Description

The graphics tool creates Earth data annotation graphics in the form of a byte-valued variable. Each output byte in the new variable contains 8 bits, one for each of 8 possible graphics planes numbered 1 to 8 from the least significant bit to the most significant bit. The graphics planes are independent of one another and encode a bitmask for graphical data annotation, where a bit value of 0 is interpreted as 'off' and a bit value of 1 as 'on'. In this way, 8 separate binary bitmasks may be encoded into one byte value. For example a pixel with graphics planes 2, 3, and 4 on is encoded as:

```
Binary value  = 00001110
Decimal value = 14
```

Following the standard convention for graphics planes in CoastWatch product files, the default behaviour places latitude/longitude grid graphics in plane 2, coast line graphics in plane 3, and land mask graphics in plane 4. Coast lines are derived from GSHHS coast line data, and land polygons are filled GSHHS polygons (see http://www.ngdc.noaa.gov/mgg/shorelines/gshhs.html). The default output variable name is 'graphics'. These defaults may be changed using command line options to alter the planes used for each type of annotation, to exclude or add some types of annotation, and to change the output variable name.

Once the graphics planes are created, they may be used as overlay graphics for rendered Earth data images. The graphics byte data may be exported using the cwexport tool for use in other software

packages, or may be used in the cwrender tool with the **--bitmask** option.

Parameters

Main parameters:

input The input data file name.

output The output file name. If the output file name is not specified, the input file name is used and the new variable must not already exist in the input file.

Options:

-c, --coast=PLANE The coast line graphics plane. The default is plane 3. If the plane value is 0, no coast graphics are rendered.

-g, --grid=PLANE The grid line graphics plane. The default is plane 2. If the plane value is 0, no grid graphics are rendered.

-h, --help Prints a brief help message.

-l, --land=PLANE The land mask graphics plane. The default is plane 4. If the plane value is 0, no land graphics are rendered.

-p, --political=PLANE The political line graphics plane. There is no default plane for political lines, as they are normally excluded from rendering.

-v, --verbose Turns verbose mode on. The current status of data rendering is printed periodically. The default is to run quietly.

-V, --variable=NAME The output variable name. The default name is 'graphics'.

Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.
- Invalid input or output file names.
- Unsupported input file format.
- Output variable already exists in input file.

Examples

The following shows the creation of a standard set of graphics planes using cwgraphics. The file being acted upon is a CoastWatch HDF file created using the graphical cwmaster tool:

```
phollema@localhost:<~/cwatch/satdata/hdf> cwgraphics -v bc_coast.hdf
cwgraphics: Reading input bc_coast.hdf
cwgraphics: Creating graphics variable
cwgraphics: Rendering overlay at plane 2
cwgraphics: Rendering overlay at plane 3
cwgraphics: Rendering overlay at plane 4
```

Another example below shows the alteration of the default options. Only coast line and political line graphics are rendered to plane 1, and the output variable is named 'geography':

```
phollema@localhost:<~/cwatch/satdata/hdf> cwgraphics -v --land 0
  --grid 0 --coast 1 --political 1 --variable geography bc_coast.hdf
cwgraphics: Reading input bc_coast.hdf
cwgraphics: Creating geography variable
cwgraphics: Rendering overlay at plane 1
cwgraphics: Rendering overlay at plane 1
cwgraphics: Rendering overlay at plane 1
```

A.9 cwimport

Name

cwimport - translates Earth data into CoastWatch HDF.

Synopsis

cwimport [OPTIONS] input1 [input2 ...] output

Options:

-h, --help
-m, --match=PATTERN
-v, --verbose

Description

The import tool translates Earth data into CoastWatch HDF format. Multiple input files may be specified, but must have matching Earth transforms and dates. The utility loops over all input files and creates a single CoastWatch HDF output file. The utility does not handle multiple variables with the same name -- if a variable in an input file is encountered with the same name as an existing variable from a previous input file, the new variable is skipped. Options are available to alter verbosity and variable name matching.

Parameters

Main parameters:

input1 [input2 ...] The input data file name(s). At least one input file is required. If multiple files are specified, they must have matching dates and Earth transforms. The currently supported input formats are CoastWatch HDF, CoastWatch IMGMAP, TeraScan HDF, and NOAA 1b packed format GAC/LAC/HRPT AVHRR.

output The output data file name.

Options:

-h, --help Prints a brief help message.

-m, --match=PATTERN The variable name matching pattern. If specified, the pattern is used as a regular expression to match variable names. Only variables matching the pattern will be imported. By default, no pattern matching is performed and all variables are imported.

-v, --verbose Turns verbose mode on. The current status of data conversion is printed periodically. The default is to run quietly.

Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.
- Invalid input or output file names.
- Unsupported input file format.
- Input file dates or Earth transforms do not match.

Examples

The following shows the import of several .cwf files to CoastWatch HDF with verbose mode on:

```
phollema@localhost:<~/cwatch/satdata> cwimport --verbose
  2002_214_2057_n16_wv_*.cwf 2002_214_2057_n16_wv.hdf

cwimport: Converting file [1/2], 2002_214_2057_n16_wv_c2.cwf
cwimport: Writing avhrr_ch2
cwimport: Writing graphics
cwimport: Converting file [2/2], 2002_214_2057_n16_wv_c4.cwf
cwimport: Writing avhrr_ch4
cwimport: Writing graphics
cwimport: Variable 'graphics' already exists, skipping
```

A.10 cwinfo

Name

cwinfo - prints Earth data file information.

Synopsis

cwinfo [OPTIONS] input

Options:

-h, --help
-t, --transform
-v, --verbose

Description

The information utility dumps Earth data information in a display-friendly format. The global Earth information is printed such as satellite name, sensor, date, and Earth transform information. The name of each variable is printed along with its data type, dimensions, scaling factor, and so on. For more detailed printing of generic HDF file contents, use the HDF hdp command.

When the **--transform** option is used, various additional Earth transform information is printed. Let nc and nr be the x and y coordinate dimensions respectively, and mc=(nc-1)/2, mr=(nr-1)/2 be the midpoint coordinates. Note that indexing is zero-based and coordinates refer to the pixel center. Then the following information is computed:

- Pixel width at (mc,mr)
- Pixel height at (mc,mr)
- Total width from (0,mr) to (nc-1,mr)
- Total height from (mc,0) to (mc,nr-1)
- Center lat/lon at (mc,mr)
- Upper-left lat/lon at (0,0)
- Upper-right lat/lon at (mc-1,0)
- Lower-left lat/lon at (0,mr-1)
- Lower-right lat/lon at (mc-1,mr-1)

Parameters

Main parameters:

input The input data file name.

Options:

-h, --help Prints a brief help message.

-t, --transform Specifies that additional Earth transform information should also be printed. The default is to show only global and variable information.

-v, --verbose Turns verbose mode on. The current status of automatic file identification is printed. This output is useful when trying to understand why a certain file is not being recognized by this and other tools. The default is to run quietly.

Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.
- Invalid input file name.
- Unsupported input file format.

Examples

The following shows an information dump of a CoastWatch HDF file from the West Coast:

```
phollema@localhost:<~/cwatch/satdata> cwinfo 2002_197_1100_n16_wn.hdf

Contents of file 2002_197_1100_n16_wn.hdf

Global information:
  Satellite:        noaa-16
  Sensor:           avhrr
  Date:             2002/07/16 JD 197
  Time:             11:00:08 UTC
  Pass type:        night
  Projection type:  mapped
  Map projection:   mercator
  Map affine:       0 -1469.95 1469.95 0 -15012623.67 6367109.52
  Origin:           USDOC/NOAA/NESDIS CoastWatch
```

```
Variable information:
  Variable       Type    Dimensions  Units          Scale     Offset
  avhrr_ch3      short   1024x1024   temp_deg_c     0.01      0
  avhrr_ch4      short   1024x1024   temp_deg_c     0.01      0
  avhrr_ch5      short   1024x1024   temp_deg_c     0.01      0
  sst            short   1024x1024   temp_deg_c     0.01      0
  cloud          byte    1024x1024   -              -         -
  sat_zenith     short   1024x1024   -              0.0001    0
  graphics       byte    1024x1024   -              -         -
```

A.11 cwmaster

Name

cwmaster - creates map projection master datasets.

Synopsis

cwmaster [OPTIONS] input
cwmaster [OPTIONS]

Options:

-h, --help
-n, --splash

Description

The master utility creates map projection master data sets using a graphical user interface. A master projection specifies the translation between grid row and column coordinates and Earth latitude and longitude coordinates. A number of common map projections are available such as Mercator, Transverse Mercator, Polar Stereographic, Orthograpic, Lambert Conformal Conic, and so on. Detailed help on the usage of cwmaster is available from within the utility using the menu bar under *Help | Help and Support* .

Parameters

Main parameters:

input The input data file name. If specified, the data file is opened and used as the initial map projection master.

Options:

-h, --help Prints a brief help message.

-s, --splash Shows the splash window on startup. The splash window shows the version, author, and web site information.

Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.
- Invalid input file name.
- Unsupported input file format.
- Input file does not contain a map projection.

Examples

The following shows the use of cwmaster to load master parameters from a CoastWatch IMGMAP file:

```
phollema@localhost:<~/cwatch/satdata/2002_319_2144_n16_wl> cwmaster
  2002_319_2144_n16_wl_c2.cwf
```

A.12 cwmath

Name

cwmath - combines Earth data using a mathematical expression.

Synopsis

cwmath [OPTIONS] input
cwmath [OPTIONS] input1 [input2 ...] output

Options:

-c, --scale=FACTOR/OFFSET
-e, --expr=EXPRESSION
-h, --help
-l, --longname=STRING
-s, --size=TYPE
-t, --template=VARIABLE
-u, --units=STRING
-v, --verbose

Description

The math tool combines Earth data using a mathematical expression. The expression takes the form:

```
variable = formula
```

where the variable is the output variable to create and the formula is a mathematical combination of input variables. The formula may contain a number of standard operators, for example addition and subtraction, as well as functions such as sine and cosine and numerical and symbolic constants. The supported operators and functions are as follows:

Operator	Symbol
Power	^
Boolean Not	!
Unary Plus, Unary Minus	+x, -x
Modulus	%
Division	/
Multiplication	*
Addition, Subtraction	+, -
Less or Equal, More or Equal	<=, >=
Less Than, Greater Than	<, >
Not Equal, Equal	!=, ==
Boolean And	&&
Boolean Or	||

Function	Calling sequence
Sine	sin (x)
Cosine	cos (x)
Tangent	tan (x)
Arc Sine	asin (x)
Arc Cosine	acos (x)
Arc Tangent	atan (x)
Hyperbolic Sine	sinh (x)
Hyperbolic Cosine	cosh (x)
Hyperbolic Tangent	tanh (x)
Inverse Hyperbolic Sine	asinh (x)
Inverse Hyperbolic Cosine	acosh (x)
Inverse Hyperbolic Tangent	atanh (x)
Natural Logarithm	ln (x)
Logarithm base 10	log (x)
Angle	angle (x)
Absolute Value / Magnitude	abs (x)
Random number (between 0 and 1)	rand ()
Modulus	mod (x)
Square Root	sqrt (x)
Sum	sum (x1, x2, ...)
if (condition is true) then return (x1) else return (x2)	select (condition, x1, x2)
Hexadecimal decoder	hex (string)
if (b (BITWISE OR) mask == 0) then return (x) else return (Not-a-Number)	mask (x, b, mask)
Bitwise And	and (x1, x2)
Bitwise Or	or (x1, x2)
Bitwise Xor	xor (x1, x2)
Bitwise Not	not (x)

Constant	Value
e	2.7182818...
pi	3.1415927...
nan (Not-a-Number)	NaN

Note that boolean expressions are evaluated to be either 1 or 0 (true or false respectively).

Parameters

Main parameters:

input The single input and output data file. In the case that a single input file is specified and no output file, data is read from and written to the same file. The new variable created by the expression must not already exist in the input file.

input1 [input2...] The input data file name(s). If multiple input files are specified, variables on the right hand side of the expression (or used in the **--template** option) must be prefixed by the string 'file<N>_' where <N> is replaced with the index of the input file which contains the variable and input file indexing starts at 1. For example, to reference the variable 'avhrr_ch4' in the second input file, use 'file2_avhrr_ch4' in the expression.

output The output data file name. If specified and the file does not already exist, it will be created using metadata from the first input file. If it does exist, it will be opened and checked for a compatible Earth transform and the new variable data will be added to the file. The new variable created by the expression must not already exist in the output file. The output file can be one of the input files if needed.

Options:

-c, –scale=FACTOR/OFFSET The output variable scale and offset. The scaling is used to store floating-point values as integers using the equation:

```
integer = value/factor + offset
```

The default is '0.01,0'. This option is ignored if **--size** is 'float'.

-e, --expr=EXPRESSION The mathematical expression. See above for the expression syntax and supported operators and functions. If no expression is specified, the user will be prompted to enter an expression at the keyboard. The latter method is recommended for operating systems such as Microsoft Windows in which the command line shell can mangle some expression characters such as the equals sign.

-h, --help Prints a brief help message.

-l, --longname=STRING The output variable long name. The long name is a verbose string to describe the variable in common terms. For example, the variable named 'sst' might have the long name 'sea surface temperature'. The default is to use the output variable name as the long name.

-s, --size=TYPE The output variable value size. Valid choices are 'byte' or 'ubyte' for 8-bit signed or unsigned bytes, 'short' or 'ushort' for 16-bit signed or unsigned integers, and 'float' for 32-bit floating-point values with no scaling. The default is 'short'.

-t, --template=VARIABLE The output template variable. When a template is used, the output variable size, scaling, units, long name, and missing value are all determined from the template variable. Any of these properties set from the command line override the corresponding template property. There is no default template variable.

-u, --units=STRING The output variable units. For example if the output variable data is based on temperature in Celsius, the variable units might be 'celsius'. There is no default units value.

-v, --verbose Turns verbose mode on. The current status of computation is printed periodically. The default is to run quietly.

Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.
- Invalid input or output file names.
- Unsupported input file format.
- Invalid mathematical expression.
- Output variable already exists in input file.
- Invalid scale or size specified.
- Unsupported variable rank detected.
- Invalid expression variable name.

Examples

The following shows the correction of AVHRR channel 2 data for solar zenith angle. The output variable is named 'avhrr_ch2_corr' and is written to the input file:

```
phollema@localhost:<~/cwatch/satdata/hdf> cwmath -v --units
  "percent" --longname "AVHRR channel 2 corrected"
  --expr "avhrr_ch2_corr = avhrr_ch2/cos(sun_zenith*pi/180)"
  2003_104_1513_n17_er.hdf

cwmath: Reading input 2003_104_1513_n17_er.hdf
cwmath: Creating avhrr_ch2_corr variable
cwmath: Computing row 0
cwmath: Computing row 100
```

```
cwmath: Computing row 200
cwmath: Computing row 300
...
```

Another example below shows the computation of Normalized Difference Vegetation Index (NDVI):

```
phollema@localhost:<~/cwatch/satdata/hdf> cwmath -v --longname
  "Normalized Difference Vegetation Index"
  --expr "ndvi = (avhrr_ch2 - avhrr_ch1)/(avhrr_ch2 + avhrr_ch1)"
  2003_104_1513_n17_er.hdf

cwmath: Reading input 2003_104_1513_n17_er.hdf
cwmath: Creating ndvi variable
cwmath: Computing row 0
cwmath: Computing row 100
cwmath: Computing row 200
cwmath: Computing row 300
...
```

In order to demonstrate the use of the 'mask' function, the example below shows the masking of the 'sst' variable using the 'cloud' variable. Note that a hexadecimal value is used to determine which values from the cloud mask are used in the masking procedure. Since the cloud data is represented by 8-bit bytes, the hexadecimal mask value need only specify two hexadecimal digits. In this case, the value '0x6f' represents bits 1, 2, 3, 4, 6, and 7 (for all cloud mask bits, the value would be '0xff'):

```
phollema@localhost:<~/cwatch/satdata/hdf> cwmath -v --template sst
  --expr 'sst_masked = mask (sst, cloud, hex ("0x6f"))'
  2003_104_1513_n17_er.hdf

cwmath: Reading input 2003_104_1513_n17_er.hdf
cwmath: Creating sst_masked variable
cwmath: Computing row 0
cwmath: Computing row 100
cwmath: Computing row 200
cwmath: Computing row 300
...
```

A final example below shows how the tool may be used to compute complex formulas using a Unix Bourne shell script. The example computes the theoretical AVHRR channel 3b albedo at night for NOAA-17 using actual channel 3b temperatures and channel 3b emission temperatures estimated from channel 4 and 5:

```
#!/bin/sh

input=$1
T3E_A=6.82947
T3E_B=0.97232
T3E_C=1.66366
ZERO_C=273.15
t3="(avhrr_ch3 + $ZERO_C)"
t4="(avhrr_ch4 + $ZERO_C)"
t5="(avhrr_ch5 + $ZERO_C)"
t3e="($T3E_A + $T3E_B*$t4 + $T3E_C*($t4 - $t5))"
planck_c1=1.1910427e-5
planck_c2=1.4387752
w3=2669.3554
c3b_a=1.702380
c3b_b=0.997378
rad3="(($planck_c1*($w3^3)) / (e^(($planck_c2*$w3)/($c3b_a + $c3b_b*$t3)) - 1.0))"
rad3e="(($planck_c1*($w3^3)) / (e^(($planck_c2*$w3)/($c3b_a + $c3b_b*$t3e)) - 1.0))"
alb3="(100*(1 - $rad3/$rad3e))"
cwmath -v --longname "AVHRR channel 3 albedo" --units "percent" \
  --expr "avhrr_ch3_albedo=$alb3" $input
```

A.13 cwnavigate

Name

cwnavigate - adds navigational corrections to Earth data.

Synopsis

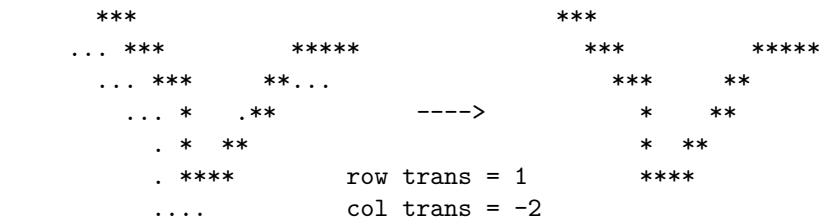
cwnavigate [OPTIONS] {-t, --trans=ROWS/COLS} input
cwnavigate [OPTIONS] {-r, --rotate=ANGLE} input
cwnavigate [OPTIONS] {-a, --affine=A/B/C/D/E/F} input
cwnavigate [OPTIONS] {-R, --reset} input

Options:

-h, --help
-m, --match=PATTERN
-v, --verbose

Description

The navigation tool adds navigational corrections to 2D variables in an Earth data file by setting navigational transform parameters. The most basic navigational transform consists of additive translation in the row and column data coordinates. As an example of translation, the following diagram shows coastlines in the Earth image data as a '.' (period) symbol and coastlines derived from a GIS database as a '*' (star). Translation has been used to correct the position of the image data:



A more generic navigational transform consists of a translation combined with a rotation or shear. To represent generic navigational transforms, an affine transform matrix is used to convert "desired" data coordinates to "actual" data coordinates as follows:

$$\begin{vmatrix} row' \\ 1 \end{vmatrix} = \begin{vmatrix} a & c & e \\ b & d & f \\ 0 & 0 & 1 \end{vmatrix} \begin{vmatrix} row \\ col \\ 1 \end{vmatrix}$$

```
|    |   |       |  |   |
|col'| = |b  d  f|  |col|
|    |   |       |  |   |
| 1  |   |0  0  1|  | 1 |
```

where [a..f] are the affine transform matrix coefficients and (row',col') is the actual data coordinates at which the desired data value for (row,col) may be found.

To apply a navigational transform to a 2D variable, the existing navigational transform is read and the new transform is applied to it using matrix multiplication to create a combined transform. As an example, suppose that T1 is the initial navigational transform. The application of an additional transform T2 results in a new transform that is equivalent to:

```
T2 (T1 (row, col))
```

A navigational transform can be applied to a subset of 2D variables, or all variables in the file. Note that satellite channel data or channel-derived variables should be corrected with navigation but GIS-derived variables such as coastline and lat/lon grid graphics should not be corrected. Setting the navigational transform simply establishes a mapping between desired and actual data coordinates -- it does not change the gridded data values themselves. Once a navigational transform has been set, other CoastWatch tools in this package will take the transform into account when reading the data.

Parameters

Main parameters:

-t, --trans=ROWS/COLS The translation transform to apply. The actual row and column coordinates are calculated by adding the specified row and column translation to the desired coordinates.

-r, --rotate=ANGLE The rotation transform to apply. The actual row and column coordinates are calculated by rotating the desired row and column coordinates about the data center by the specified angle in degrees. Positive angles rotate counter-clockwise while negative angles rotate clockwise.

-a, --affine=A/B/C/D/E/F The explicit affine transform to apply. The coefficients are used to form the affine transform matrix (see the Description section above) which is applied to the existing transform using matrix multiplication.

-R, --reset Specifies that the existing navigational transform should be reset to the identity. Under the identity transform, no navigational correction is performed.

input The input data file name. The navigational corrections are applied to the input file in-situ. For CoastWatch HDF files, the corrections are applied to individual variables. For CoastWatch IMGMAP files, corrections are applied to the global attributes and the **--match** option has no effect. No other file formats are supported.

Options:

-h, --help Prints a brief help message.

-m, --match=PATTERN The variable name matching pattern. If specified, the pattern is used as a regular expression to match variable names. Only variables matching the pattern will be navigated. By default, no pattern matching is performed and all variables are navigated.

-v, --verbose Turns verbose mode on. The status of navigational correction is printed periodically. The default is to run quietly.

Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.
- Invalid input file name.
- Unsupported input file format.
- Unsupported navigational correction.

Examples

The following example shows the navigational correction of a NOAA-15 CoastWatch HDF data file from the Gulf of Mexico:

```
phollema@localhost:<~/cwatch/satdata> cwnavigate --trans -3/3 -v
  --match '(avhrr.*|cloud|sst)' 2002_328_1326_n15_ml.hdf

cwnavigate: Reading input 2002_328_1326_n15_ml.hdf
cwnavigate: Applying navigational correction to avhrr_ch1
cwnavigate: Applying navigational correction to avhrr_ch2
cwnavigate: Applying navigational correction to avhrr_ch4
cwnavigate: Applying navigational correction to cloud
cwnavigate: Applying navigational correction to sst
```

Another example below shows the navigational correction of a NOAA-15 CoastWatch IMGMAP data file from the US east coast:

```
phollema@localhost:<~/cwatch/satdata> cwnavigate --trans -2/1 -v
  2002_326_1330_n15_er_c2.cwf

cwnavigate: Reading input 2002_326_1330_n15_er_c2.cwf
```

```
cwnavigate: Applying navigational correction
```

A.14 cwregister

Name

cwregister - resamples gridded Earth data to a master projection.

Synopsis

cwregister [OPTIONS] master input output

Options:

-h, --help
-m, --match=PATTERN
-M, --method=TYPE
-O, --overwrite=TYPE
-p, --polysize=KILOMETERS
-r, --rectsize=WIDTH/HEIGHT
-v, --verbose

Description

The register tool resamples gridded Earth data to a master projection. A master projection specifies the translation between grid row and column coordinates and Earth latitude and longitude coordinates. The master projection file is any valid Earth data file from which a set of row and column dimensions and Earth transform parameters may be extracted. This includes standard CoastWatch product files as well as master files created using the **cwmaster** tool.

Parameters

Main parameters:

master The master projection file name. Note that the master file is not altered in any way. It is simply accessed in order to determine grid and Earth transform parameters.

input The input data file name.

output The output data file name.

Options:

-h, --help Prints a brief help message.

-m, --match=PATTERN The variable name matching pattern. If specified, the pattern is used as a regular expression to match variable names. Only variables in the input file matching the pattern will be registered. By default, no pattern matching is performed and all variables are registered.

-M, --method=TYPE The registration resampling method. Valid methods are 'inverse' and 'mixed'. The inverse resampling method divides the destination into rectangles of bounded physical size (see the **--polysize** option), and computes polynomial approximations for the coordinate transforms on each rectangle in order to determine a source coordinate for each destination coordinate. This is the default method and recommended when the source coordinate transform is smooth and continuous in the destination coordinate space such as with AVHRR LAC swath data. The mixed resampling method divides the source into rectangles of certain dimensions (see the **--rectsize** option), computes polynomials on each rectangle similar to the inverse method, and follows with a single pixel interpolation. This method is recommended when the source coordinate transform is discontinuous at regular intervals in the destination coordinate space, such as with MODIS swath data.

-O, --overwrite=TYPE ADVANCED USERS ONLY. Sets the overwrite policy for 'mixed' mode resampling: either 'always' (the default), 'never', or 'closer'. If during resampling, more than one source pixel maps to a single destination pixel, this option is used to determine if the new value should overwrite the old value. By default, the new value always overwrites the destination pixel (the 'always' mode). If 'never' is specified, the first written value is never overwritten. If 'closer' is specified, the destination pixel is only overwritten if the source pixel is closer in physical location to the destination than any previous source pixel.

-p, --polysize=KILOMETERS The polynomial approximation rectangle size in kilometers. This option is only used by the inverse resampling method (see the **--method** option). The inverse resampling method employs a polynomial approximation to speed up the calculation of data locations. The polynomial rectangle size determines the maximum allowed size of the resampling rectangles in the destination. The default polynomial size is 100 km, which introduces an error of less than 0.15 km for AVHRR LAC data.

-r, --rectsize=WIDTH/HEIGHT The polynomial approximation rectangle size in pixels. This option is only used by the mixed resampling method (see the **--method** option). The mixed resampling method employs a polynomial approximation to speed up the calculation of data locations. The polynomial rectangle size determines the exact dimensions of the resampling rectangles in the source. The default polynomial rectangle size is 50/50, which introduces only a small error for AVHRR LAC data.

-v, --verbose Turns verbose mode on. The current status of data conversion is printed periodically. The default is to run quietly.

Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.
- Invalid master, input or output file names.
- Unsupported master or input file format.

Examples

The following shows the registration of NOAA-17 AVHRR channel 2 swath data to a southern California master:

```
phollema@localhost:<~/cwatch/satdata/2002_318_1826_n17_mo> cwregister
  -v --match avhrr_ch2 ws_master.hdf 2002_318_1826_n17_mo.hdf
  2002_318_1826_n17_ws.hdf

cwregister: Reading master ws_master.hdf
cwregister: Reading input 2002_318_1826_n17_mo.hdf
cwregister: Creating output 2002_318_1826_n17_ws.hdf
cwregister: Adding avhrr_ch2 to resampled grids
GridResampler: Found 1 grid(s) for resampling
GridResampler: Resampling 4788x2048 to 1024x1024
GridResampler: Creating location estimators
GridResampler: Computing row 0
GridResampler: Computing row 100
GridResampler: Computing row 200
GridResampler: Computing row 300
GridResampler: Computing row 400
GridResampler: Computing row 500
GridResampler: Computing row 600
GridResampler: Computing row 700
GridResampler: Computing row 800
GridResampler: Computing row 900
GridResampler: Computing row 1000
cwregister: Closing files
```

A.15 cwrender

Name

cwrender - performs Earth data visualization.

Synopsis

cwrender {-c, --composite=RED/GREEN/BLUE} [OPTIONS] input output
cwrender {-e, --enhance=VARIABLE1[/VARIABLE2]} [OPTIONS] input output

General options:

-h, --help
-v, --verbose

Output content and format options:

-a, --noantialias
-f, --format=TYPE
-i, --indexed
-I, --imagecolors=NUMBER
-l, --nolegends
-m, --magnify=LATITUDE/LONGITUDE/FACTOR
-o, --logo=NAME
-s, --size=PIXELS
-T, --tiffcomp=TYPE
-W, --worldfile=FILE

Plot overlay options:

-A, --bath=COLOR[/LEVEL1/LEVEL2/...]
-b, --bitmask=VARIABLE/MASK/COLOR
-C, --coast=COLOR[/FILL]
-d, --cloud=COLOR
-g, --grid=COLOR
-H, --shape=FILE/COLOR[/FILL]
-L, --land=COLOR
-p, --political=COLOR
-S, --nostates
-t, --topo=COLOR[/LEVEL1/LEVEL2/...]
-u, --group=GROUP
-w, --water=COLOR
-X, --exprmask=EXPRESSION/COLOR

Color enhancement options:

-E, --enhancevector=STYLE/SYMBOL[/SIZE]
-F, --function=TYPE
-k, --background=COLOR
-M, --missing=COLOR
-P, --palette=NAME
-r, --range=MIN/MAX
-U, --units=UNITS

Color composite options:

-B, --bluerange=MIN/MAX
-G, --greenrange=MIN/MAX
-R, --redrange=MIN/MAX
-x, --redfunction=TYPE
-y, --greenfunction=TYPE
-z, --bluefunction=TYPE

Description

Overview

The render tool performs Earth data visualization by converting 2D data sets in the input file to color images. The data values are converted from scientific units to a color using either an enhancement function and color palette or by performing a color composite of three data variables -- one for each of the red, green, and blue color components. The resulting Earth data plot may have legends displaying the color scale, data origin, date, time, projection info, as well as data overlays showing latitude/longitude grid lines, coast lines, political boundaries, masks, and shapes.

Overlay colors

Overlay colors may be specified using simple color names such as 'red', 'gray', 'cyan', 'blue', and 'green'. Overlays may be made to appear slightly transparent (allowing the color behind to show through) by following the color name with a colon ':' and a transparency value in percent, for example 'red:50' would make the overlay red with a 50% transparency. Transparency values range from 0 (completely opaque) to 100 (completely transparent).

Colors may also be specified using explicit hexadecimal notation for red/green/blue color components and optional alpha component as follows:

```
0xAARRGGBB
  ^ ^ ^ ^
  | | | ----- Blue              \
  | | ------- Green             |---- Range: 00 -> ff
```

```
| --------- Red               |
---------- Alpha (optional)  /
```

Note that the prepended '0x' denotes a hexadecimal constant, and must be used even though it is not part of the color component values. As an example, the simple color names above may be specified as hexadecimal values:

```
0xff0000    red
0x555555    gray
0x00ffff    cyan
0x0000ff    blue
0x00ff00    green
0x80ff0000  red, 50% transparent
```

Rendering order

The data view itself (not including the legends) is rendered in such a way that overlays may overlap each other. For example, latitude/longitude grid lines may fall on top of land polygons because the grid overlay is rendered after the coastline overlay. Knowing the order in which the data and overlays are rendered may answer some questions if the data view doesn't look the way the user expects. The data view is rendered in the following order:

1. Before any overlay or data, the data view is filled with a background color (normally white) for vector plots or a missing color (normally black) for color enhancement or color composite plots.
2. Color vectors or image pixels are rendered to the data view. The background or missing color will show though where no vectors or pixels were rendered.
3. Data overlays are rendered to the view in the following order (see the description of each option below):
   - Cloud mask (**--cloud**)
   - Bit masks (**--bitmask**), possibly more than one
   - Expression masks (**--exprmask**), possibly more than one
   - Water mask (**--water**)
   - Bathymetric contours (**--bath**)
   - Land mask (**--land**)
   - Coastline and filled land polygons (**--coast**)
   - Political lines (**--political**)
   - Topography contours (**--topo**)
   - Shape files (**--shape**), possibly more than one
   - Latitude/longitude grid lines (**--grid**)
   - Overlay groups (**--group**)

Parameters

Main parameters:

-c, --composite=RED/GREEN/BLUE Specifies color composite mode using the named variables. The data variable values are converted to colors using an individual linear enhancement function for each variable. The data values are scaled to the range [0..255] and used as the red, green, and blue components of each pixel's color. Either this option or **--enhance** must be specified, but not both.

-e, --enhance=VARIABLE1[/VARIABLE2] Specifies color enhancement mode using the named variable(s). The data variable values are converted to colors using an enhancement function and color palette. Either this option or **--composite** must be specified, but not both. If one variable name is specified, the plot shows color-enhanced image data. If two variable names are specified, the plot shows color-enhanced vectors whose direction is derived using the two variables as vector components. See the **--enhancevector** and **--background** options for settings that are specific to vector plots.

input The input data file name.

output The output image file name. Unless the **--format** option is used, the file extension indicates the desired output format: '.png', '.jpg', '.tif', or '.pdf'.

General options:

-h, --help Prints a brief help message.

-v, --verbose Turns verbose mode on. The current status of data rendering is printed periodically. The default is to run quietly.

Output content and format options:

-a, --noantialias Turns off line and font antialiasing. By default, the edges of lines and fonts are smoothed using shades of the drawing color. It may be necessary to turn off antialiasing if the smoothing is interfering with the readability of annotation graphics, such as in the case of very small fonts. This option only effects raster image output formats such as PNG, GIF and JPEG.

-f, --format=TYPE The output format. The current formats are 'png' for Portable Network Graphics, 'gif' for Graphics Interchange Format, 'jpg' for Joint Picture Experts Group, 'tif' for Tagged Image File Format with geolocation tags (GeoTIFF), 'pdf' for Portable Document Format, or 'auto' to detect the format from the output file name. The default is 'auto'. The correct choice of output format is governed by the desired use of the rendered image as follows:

- **PNG** is a non-lossy compressed image format supported by most web browsers and image manipulation software. It has similar data compression characteristics to GIF and additionally supports 24-bit color images.
- **GIF** is a non-lossy compressed format also supported by most web browsers and image manipulation software. The GIF files produced use LZW compression. Images stored in GIF format are run through a color quantization algorithm to reduce the color map to 256

colors or less. Although file sizes are generally smaller than PNG, image quality may be compromised by the reduced color map.

- **JPEG** is a lossy compressed format that should be used with caution for images with sharp color lines such as those found in text and annotation graphics. The JPEG format generally achieves higher compression than PNG or GIF resulting in smaller image file sizes.
- **GeoTIFF** is a flexible image format with support for Earth location metadata. Many popular GIS packages handle GeoTIFF images and allow the user to combine a GeoTIFF base map image with other sources of raster and vector data. The GeoTIFF images generated are non-lossy uncompressed image data (unless a compression is specified using **--tiffcomp**), and can be much larger than the corresponding PNG, GIF, or JPEG. Since GeoTIFF images are generally destined for import into a GIS system, the use of this format turns on the **--nolegends** option. In general the GeoTIFFs generated are 24-bit colour images, but when no overlays are specified or the **--indexed** or **--imagecolors** options are used, a special 8-bit paletted image file is generated and comments describing the data value scaling are inserting into the image description tags.
- **PDF** is a standard for high quality publishing developed by Adobe Systems and is used for output to a printer via such tools as the Adobe Acrobat Reader. In general PDF files are slightly larger than the equivalent PNG but retain highly accurate vector graphics components such as lines and fonts.

-i, --indexed Short for **--imagecolors 256** . See the **--imagecolors** option below.

-I, --imagecolors=NUMBER The number of colors to use for the index color model of the data image, up to 256. Normally the data image uses an unlimited number of colors because this achieves the best visual rendering quality. But in some cases it may be desirable to make the output file smaller by limiting the number of colors to <=256 values and using a index color model so that each data pixel can be represented as 8-bit bytes. This option can only be used with PNG, GIF, GeoTIFF, and PDF output formats, and only with color enhancements, not color composites. While in index color mode, antialiasing is turned off.

-l, --nolegends Turns the plot legends off. By default, the Earth data view is shown in a frame on the left and to the right color scale and plot information legends are drawn. With no legends, the Earth data is simply rendered by itself with no frame, borders, or legends.

-m, --magnify=LATITUDE/LONGITUDE/FACTOR The magnification center and factor. The data view is set to the specified center and pixel magnification factor. The center position is specified in terms of Earth location latitude and longitude in the range [-90..90] and [-180..180] and the magnification factor as a fractional number (0..1] where factors > 1 magnify and factors < 1 shrink. By default, the data view shows the entire data field with an optimal magnification factor to fit the desired view size (see **--size**).

-o, --logo=NAME The logo used for plot legends. The current predefined logo names are 'noaa3d' (the default), 'nasa3d', 'nws3d', 'doc3d', and their corresponding non-3D versions 'noaa', 'nasa', 'nws', and 'doc'. The predefined logos are named for their respective government agencies: NOAA, NASA, National Weather Service (NWS), and Department of Commerce (DOC). The user may also specify a custom logo file name, which can be any PNG, GIF, or JPEG file.

-s, --size=PIXELS The Earth data view size in pixels. The data view is normally accompanied by a set of legends unless the **--nolegends** option is used. By default, the view size is 512 pixels, plus the size of any legends.

-T, --tiffcomp=TYPE The TIFF compression algorithm. The valid types are 'none' for no compression (the default), 'deflate' for ZIP style compression, and 'pack' for RLE style PackBits compression. This option is only used with GeoTIFF output.

-W, --worldfile=FILE The name of the world file to write. A world file is an ASCII text file used for georeferencing images that contains the following lines:

- Line 1: x-dimension of a pixel in map units
- Line 2: rotation parameter
- Line 3: rotation parameter
- Line 4: NEGATIVE of y-dimension of a pixel in map units
- Line 5: x-coordinate of center of upper left pixel
- Line 6: y-coordinate of center of upper left pixel

World files may be written for any GIF, PNG, or JPEG image. The use of this option turns on the **--nolegends** option. The convention used in GIS is to name the world file similarly to the image file, but with a different extension. GDAL expects world files with a ".wld" extension, where as ESRI applications expect ".pgw" for PNG, ".gfw" for GIF, and ".jgw" for JPEG. Users should name their world files accordingly.

Plot overlay options:

-A, --bath=COLOR[/LEVEL1/LEVEL2/...] The bathymetric contour color and levels. The color is specified by name or hexadecimal value (see above). Bathymetric contours are generated for the specified integer levels in meters. If no levels are specified, contours are drawn at 200 m and 2000 m. The default is not to render bathymetric contours.

-b, --bitmask=VARIABLE/MASK/COLOR Specifies that a mask should be rendered on top of the data image whose pixels are obtained by a bitwise AND with the mask value. The named variable is used to mask the Earth data with the specified color and mask. The color is a name or hexadecimal value (see above). The mask is a 32-bit integer hexadecimal value specifying the mask bits. The bitmask is formed by bitwise ANDing the data value and mask value. If the result of the operation is non zero, the pixel is colored with the bitmask color. This option is useful for overlaying graphics on the data image when the graphics are stored as an integer valued variable in the data set. Such variables include cloud and land mask graphics. Multiple values of the **--bitmask** option may be given, in which case the masks are applied in the order that they are specified.

-C, --coast=COLOR[/FILL] The coast line color and optional fill color. The colors are specified by name or hexadecimal value (see above). The default is not to render coast lines.

-d, --cloud=COLOR The cloud mask color. The color is specified by name or hexadecimal value (see above). Cloud masking requires that a 'cloud' variable exists in the input file. The default is not to render a cloud mask.

-g, --grid=COLOR The latitude/longitude grid line color. The color is specified by name or hexadecimal value (see above). The default is not to render grid lines.

-H, --shape=FILE/COLOR[/FILL] The name and drawing/fill colors for a user-supplied shape file. The colors are specified by name or hexadecimal value (see above). The only file format currently supported is ESRI shapefile format, and only line and polygon data (no point data). The fill color is optional and is used to fill polygons if any are found in the file. Multiple values of the **--shape** option may be given, in which case the shape overlays are rendered in the order that they are specified.

-L, --land=COLOR The land mask color. The color is specified by name or hexadecimal value (see above). Land masking requires that a 'graphics' variable exists in the input file with a land mask at bit 3 where bit numbering starts at 0 for the least significant bit. The default is not to render a land mask. For an alternative to the **--land** option, try using the **--coast** option with a fill color.

-p --political=COLOR The political boundaries color. The color is specified by name or hexadecimal value (see above). The default is not to render political boundaries.

-S, --nostates Turns off state boundary rendering. The default when **--political** is specified is to render international and state boundaries. With this option is specified, only international boundaries are rendered.

-t, --topo=COLOR[/LEVEL1/LEVEL2/...] The topographic contour color and levels. The color is specified by name or hexadecimal value (see above). Topographic contours are generated for the specified integer levels in meters. If no levels are specified, contours are drawn at 200 m, 500 m, 1000 m, 2000 m, and 3000 m. The default is not to render topographic contours.

-u, --group=GROUP The overlay group name to render. Overlay groups are a concept from the CoastWatch Data Analysis Tool (CDAT). CDAT users can save a set of preferred overlays as a group and then restore those overlays when viewing a new data file. The same group names saved from CDAT are available to be rendered here. This is an extremely useful option that allows users to design a set of overlays graphically and adjust the various overlay properties beyond what can be achieved using the command line options for cwrender. If specified, this option will cause all overlays in the group to be drawn on top of any other overlays specified by command line options.

-w, --water=COLOR The water mask color. The color is specified by name or hexadecimal value (see above). Water masking is performed similarly to land masking (see the **--land** option), but the sense of the land mask is inverted. The default is not to render a water mask.

-X, --exprmask=EXPRESSION/COLOR Specifies that a mask should be rendered on top of the data image whose pixels are obtained by evaluating the expression. The color is specified by name or hexadecimal value (see above). An expression mask is a special type of multipurpose mask similar to a bitmask (see the **--bitmask** option above) but which allows the user to specify a mathematical expression to determine the mask. If the result of the expression is true (in the case of a boolean result) or non-zero (in the case of a numerical result), the data image is masked at the given location with the given color. Multiple values of the **--exprmask** option may be given, in which case the masks are applied in the order that they are specified. The syntax for the expression is identical to the right-hand-side of a **cwmath** expression (see the **cwmath** tool manual page).

Color enhancement options:

-E, --enhancevector=STYLE/SYMBOL[/SIZE] The color-enhanced vector specifications. This option is only used if two variable names are passed to the **--enhance** option. The vector style

may be either 'uvcomp' or 'magdir'; the default is 'uvcomp'. In uvcomp mode, the variables that are passed to the **--enhance** option are taken to be the U (x-direction) and V (y-direction) components of the vector. In magdir mode, the first variable is taken to be the vector magnitude, and the second to be the vector direction in degrees clockwise from north. The vector symbol may be either 'arrow' to draw arrows in the direction of the vector, or 'barb' to draw WMO wind barbs; the default is 'arrow'. If wind barbs are used, the feathered end of the barb points in the direction of the wind. Lastly, the size of the vector symbols in pixels may be specified; the default size is 10.

-F, --function=TYPE The color enhancement function. Data values are mapped to the range [0..255] by the enhancement function and range, and then to colors using the color palette. The valid enhancement function types are 'linear', 'stepN', 'log', 'linear-reverse', 'stepN-reverse', and 'log-reverse' where N is the number of steps in the function, for example 'step10'. The reverse functions are equivalent to the non-reversed functions but map data values to the range [255..0] rather then [0..255]. By default, the enhancement function is 'linear'. A log enhancement may be necessary when the data value range does not scale well with a linear enhancement such as with chlorophyll concentration derived from ocean color data.

-k, --background=COLOR The color for the background of vector plots. The color is specified by name or hexadecimal value (see above). The default background color is white.

-M, --missing=COLOR The color for missing or out of range data values. The color is specified by name or hexadecimal value (see above). The default missing color is black.

-P, –palette=NAME The color palette for converting data values to colors. The color palettes are dervied in part from the Interactive Data Language (IDL) v5.4 palettes and have similar names. The valid color palette names are as follows (line indexes are simply for reference):

```
0  BW-Linear
1  HSL256
2  RAMSDIS
3  Blue-Red
4  Blue-White
5  Grn-Red-Blu-Wht
6  Red-Temperature
7  Blue-Green-Red-Yellow
8  Std-Gamma-II
9  Prism
10 Red-Purple
11 Green-White-Linear
12 Grn-Wht-Exponential
13 Green-Pink
14 Blue-Red2
15 16-Level
16 Rainbow
17 Steps
18 Stern-Special
19 Haze
20 Blue-Pastel-Red
```

```
21 Pastels
22 Hue-Sat-Lightness-1
23 Hue-Sat-Lightness-2
24 Hue-Sat-Value-1
25 Hue-Sat-Value-2
26 Purple-Red-Stripes
27 Beach
28 Mac-Style
29 Eos-A
30 Eos-B
31 Hardcandy
32 Nature
33 Ocean
34 Peppermint
35 Plasma
36 Rainbow2
37 Blue-Waves
38 Volcano
39 Waves
40 Rainbow18
41 Rainbow-white
42 Rainbow-black
43 NDVI
44 GLERL-Archive
45 GLERL-30-Degrees
46 Chlora-1
47 Chlora-anom
48 Spectrum
49 Wind-0-50
50 CRW_SST
51 CRW_SSTANOMALY
52 CRW_HOTSPOT
53 CRW_DHW
```

By default, the 'BW-Linear' palette is used which is a gray scale color ramp from black to white.

-r, --range=MIN/MAX The color enhancement range. Data values are mapped to colors using the minimum and maximum values and an enhancement function. By default, the enhancement range is derived from the data value mean and standard deviation to form an optimal enhancement window of 1.5 standard deviation units around the mean.

-U, --units=UNITS The range and color scale units for the enhancement variable(s). By default, the user must specify the values for the **--range** option in the standard units indicated in the data. If the user prefers a different set of units to be used, they may be specified here. Many common units are accepted (and various forms of those units), for example 'kelvin', 'celsius' and 'fahrenheit' for temperature data, 'knots', 'meters per second' or 'm/s' for windspeed, and 'mg per mˆ-3' or 'kg/m-3' for concentration. For other possible unit names, see the conventions used by the Unidata UDUNITS package and its supported units file.

Color composite options:

-B, --bluerange=MIN/MAX The blue component enhancement range, see **--redrange** .

-G, --greenrange=MIN/MAX The green component enhancement range, see **--redrange** .

-R, --redrange=MIN/MAX The red component enhancement range. Data values are mapped to the range [0..255] using the minimum and maximum values and an enhancement function. By default, the enhancement range is derived from the data value mean and standard deviation to form an optimal enhancement window of 1.5 standard deviation units around the mean.

-x, --redfunction=TYPE The red component enhancement function. Data values are mapped to the range [0..255] by the enhancement function and range, and then the pixel color is created by compositing the red, green, and blue mapped values into one 32-bit integer color value. See the **--function** option for valid function types. By default, the red, green, and blue enhancements are linear.

-y, --greenfunction=TYPE The green component enhancement function, see **--redfunction** .

-z, --bluefunction=TYPE The blue component enhancement function, see **--redfunction** .

Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.
- Invalid input or output file names.
- Invalid variable name.
- Unrecognized format.
- Unrecognized color name.
- Invalid palette name.
- Invalid magnification center.

Examples

As an example of color enhancement, the following command shows the rendering of AVHRR channel 2 data from a CoastWatch HDF file to a PNG image, with coast and grid lines in red and the default linear black to white palette. We allow the routine to calculate data statistics on channel 2 for an optimal enhancement range:

```
phollema@localhost:<~/cwatch/satdata> cwrender --verbose
  --enhance avhrr_ch2 --coast red --grid red 2002_288_1435_n17_er.hdf
  2002_288_1435_n17_er_ch2.png
```

```
cwrender: Reading input 2002_288_1435_n17_er.hdf
cwrender: Normalizing color enhancement
EarthDataView: Preparing data image
EarthDataView: Rendering overlay noaa.coastwatch.render.CoastOverlay
EarthDataView: Rendering overlay noaa.coastwatch.render.GridOverlay
cwrender: Writing output 2002_288_1435_n17_er_ch2.png
```

For a color composite of the same file, the following command shows the rendering of AVHRR channels 1, 2, and 4 to a PNG image. Again, we allow the routine to calculate statistics for optimal enhancement ranges. Note that the final enhancement function is reversed in order to map warm AVHRR channel 4 values to dark and cold values to bright:

```
phollema@localhost:<~/cwatch/satdata> cwrender --verbose
  --composite avhrr_ch1/avhrr_ch2/avhrr_ch4
  --bluefunction reverse-linear --coast black --grid gray
  2002_288_1435_n17_er.hdf 2002_288_1435_n17_er_ch124.png

cwrender: Reading input 2002_288_1435_n17_er.hdf
cwrender: Normalizing red enhancement
cwrender: Normalizing green enhancement
cwrender: Normalizing blue enhancement
EarthDataView: Preparing data image
EarthDataView: Rendering overlay noaa.coastwatch.render.CoastOverlay
EarthDataView: Rendering overlay noaa.coastwatch.render.GridOverlay
cwrender: Writing output 2002_288_1435_n17_er_ch124.png
```

A further example below shows the rendering of AVHRR derived sea-surface-temperature data from the same file with a cloud mask applied. The color enhancement uses a blue to red color palette and an explicit range from 5 to 20 degrees Celsius:

```
phollema@localhost:<~/cwatch/satdata> cwrender --verbose
  --enhance sst --coast white --grid white --palette HSL256
  --range 5/20 --cloud gray 2002_288_1435_n17_er.hdf
  2002_288_1435_n17_er_sst.png

cwrender: Reading input 2002_288_1435_n17_er.hdf
EarthDataView: Preparing data image
EarthDataView: Rendering overlay noaa.coastwatch.render.BitmaskOverlay
EarthDataView: Rendering overlay noaa.coastwatch.render.CoastOverlay
EarthDataView: Rendering overlay noaa.coastwatch.render.GridOverlay
cwrender: Writing output 2002_288_1435_n17_er_sst.png
```

An example usage of the **--magnify** option is shown below to create a plot of cloud masked sea-surface-temperature data off Nova Scotia:

```
phollema@localhost:<~/cwatch/satdata> cwrender --verbose
  --enhance sst --coast white --grid white --palette HSL256
  --range 5/20 --cloud gray --magnify 43/-66/1
  2002_288_1435_n17_er.hdf 2002_288_1435_n17_er_sst_mag.png

cwrender: Reading input 2002_288_1435_n17_er.hdf
EarthDataView: Preparing data image
EarthDataView: Rendering overlay noaa.coastwatch.render.BitmaskOverlay
EarthDataView: Rendering overlay noaa.coastwatch.render.CoastOverlay
EarthDataView: Rendering overlay noaa.coastwatch.render.GridOverlay
cwrender: Writing output 2002_288_1435_n17_er_sst_mag.png
```

Known Bugs

When using the **--coast** option with a fill color and output is to a PDF file, lakes may contain a thin stripe of land in some places. In this case, use the **--land** for land filling instead.

When using the **--coast** option with a fill color, map projection discontinuities or swath projection edges may not be filled correctly.

A.16 cwsample

Name

cwsample - extracts data values at specified Earth locations.

Synopsis

cwsample {-s, --sample=LATITUDE/LONGITUDE} [OPTIONS] input output
cwsample {-S, --samples=FILE} [OPTIONS] input output

Options:

-d, --dec=DECIMALS
-D, --delimit=STRING
-h, --help
-H, --header
-i, --imagecoords
-m, --match=PATTERN
-M, --missing=VALUE
-n, --nocoords
-R, --reverse
-V, --variable=NAME1[/NAME2/...]

Description

The sampling tool extracts data values at specified Earth locations from 2D data variables. A sample point may be specified on the command line using geographic coordinates, or multiple sample points may be specified using a data file. A number of 2D data variables may be sampled simultaneously. The sampled values are printed as ASCII text to the output file, one line per sample point. Various options are available to modify the output decimals places, delimiters, and so on.

Parameters

Main parameters:

-s, --sample=LATITUDE/LONGITUDE The sample point for a single sampling operation. The point is specified in terms of Earth location latitude and longitude in the range [-90..90] and [-180..180].

-S, --samples=FILE The file name containing a list of sample points for performing multiple sampling operations. The file must be an ASCII text file containing sample points as latitude /

longitude pairs, one line per pair, with values separated by spaces or tabs. The points are specified in terms of Earth location latitude and longitude in the range [-90..90] and [-180..180].

input The input data file name.

output The output text file name. If the output file name is '-', output is sent to standard output (normally the terminal).

Options:

-d, --dec=DECIMALS The number of decimal places for printed geographic coordinate values. The default is 6 decimals.

-D, --delimit=STRING The value delimiter string. By default, values are separated with a single space character.

-h, --help Prints a brief help message.

-H, --header Specifies that a one line header should be written. The header is written before any data and consists of the output column names. By default no header is written.

-i, --imagecoords Specifies that image coordinates (row and column) should be printed for each output line. The default is to print only geographic coordinates.

-m, --match=PATTERN The variable name matching pattern. If specified, the pattern is used as a regular expression to match variable names. Only variables matching the pattern will be sampled. By default, no pattern matching is performed and all variables are sampled unless the **--variable** option is used. Note that either **--variable** or **--match** may be specified, but not both.

-M, --missing=VALUE The output value for missing or out of range data. The default is to print 'NaN' for missing values.

-n, --nocoords Turns geographic coordinate printing off. By default, each output line has the form 'latitude longitude value(s)' but with no coordinates, each line simply contains the data value(s).

-R, --reverse Specifies that coordinates should be printed in reverse order, 'longitude latitude'. The default is 'latitude longitude'.

-V, --variable=NAME1[/NAME2/...] The variable names to sample. If specified, the variable sample values are printed in columns in exactly the same order as they are listed. This option is different from the **--match** option because it (i) specifies the column order, where as **--match** orders the columns as the variables are encountered in the file, and (ii) does not support pattern matching; all variable names must be specified exactly. Without this option or the **--match** option, all variables are sampled. Note that either **--variable** or **--match** may be specified, but not both.

Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.
- Invalid input or output file names.
- Invalid sample coordinates file format.

Examples

In the example below, a sample points file named sample_locs.txt was set up to follow the 93 W longitude line at regular 0.2 degree intervals as follows:

```
28 -93
28.2 -93
28.4 -93
28.6 -93
28.8 -93
29 -93
29.2 -93
29.4 -93
29.6 -93
29.8 -93
30 -93
```

and a Gulf of Mexico data file sampled for SST and cloud data along this line with output to the terminal screen:

```
phollema@localhost:<~/cwatch/satdata> cwsample --header
  --match '(sst|cloud)' --samples sample_locs.txt
  2002_325_1546_n17_mr.hdf -

latitude longitude sst cloud
28 -93 25.24 0
28.2 -93 25.24 0
28.4 -93 24.78 0
28.6 -93 23.84 0
28.8 -93 22.72 0
29 -93 21.37 0
29.2 -93 20.06 0
29.4 -93 19.29 0
29.6 -93 18.16 0
29.8 -93 17.57 6
```

```
30 -93 17.48 22
```

Another example shows the sampling of one SST value as in the case of comparison with a single buoy measurement with output to the terminal screen:

```
phollema@localhost:<~/cwatch/satdata> cwsample --header
  --match sst --sample 28.8/-93 2002_325_1546_n17_mr.hdf -

latitude longitude sst
28.8 -93 22.72
```

A.17 cwstats

Name

cwstats - calculates Earth data file statistics.

Synopsis

cwstats [OPTIONS] input

Options:

-h, --help
-i, --region=LAT/LON/RADIUS
-l, --limit=STARTROW/STARTCOL/ENDROW/ENDCOL
-m, --match=PATTERN
-s, --stride=N
-S, --sample=FACTOR

Description

The statistics utility calculates a number of statistics for each variable in an Earth data file:

- Count - the count of total data values sampled.
- Valid - the number of valid (not missing) data values.
- Min - the minimum data value.
- Max - the maximum data value.
- Mean - the average data value.
- Stdev - the standard deviation from the mean.

To speed up the statitics calculations, a subset of the data values in each variable may be specified using either the **--stride** or **--sample** options, and the **--limit** option. The **--match** option may also be used to limit the statistics calculations to a subset of the variables.

Parameters

Main parameters:

input The input data file name.

Options:

-h, --help Prints a brief help message.

-i, --region=LAT/LON/RADIUS The sampling region for each two-dimensional variable. The region is specified by the center latitude and longitude in degrees, and the radius from the center in kilometers. Only data within the rectangle specified by the center and radius is sampled. By default, all data is sampled. Either the **--region** option or the **--limit** option may be specified, but not both.

-l, --limit=STARTROW/ENDROW/STARTCOL/ENDCOL The sampling limits for each two-dimensional variable in image coordinates. Only data between the limits is sampled. By default, all data is sampled. Either the **--region** option or the **--limit** option may be specified, but not both.

-m, --match=PATTERN The variable name matching pattern. If specified, the pattern is used as a regular expression to match variable names. Only variables matching the pattern are included in the calculations. By default, no pattern matching is performed and all variables are included.

-s, --stride=N The sampling frequency for each variable dimension. The default is to sample all data values (stride = 1).

-S, --sample=FACTOR The sampling factor for each variable. The sampling factor is a value in the range [0..1] that specifies the number of data values sampled as a fraction of the total number of data values. To sample 1 percent of all data values, the sample factor would be 0.01. The default is to sample all data values (factor = 1).

Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.
- Invalid input file name.
- Unsupported input file format.
- Error reading input data values.

Examples

The following shows a statistics calculation on a CoastWatch HDF file from the Great Lakes:

```
phollema@localhost:<~/cwatch/satdata> cwstats 2002_197_1719_n16_gr.hdf

Variable       Count     Valid     Min       Max       Mean       Stdev
avhrr_ch1      1048576   483728    3.49      74.36     13.059646  11.371605
avhrr_ch2      1048576   483728    1.97      71.35     18.520041  9.844144
```

```
avhrr_ch3a      1048576   483728    0.53      52.84     14.664213  8.88201
avhrr_ch4       1048576   483728    -44.8     31.55     11.052207  13.683309
avhrr_ch5       1048576   483728    -45.48    27.05     7.978351   13.185983
sst             1048576   483728    -44.51    51.43     20.166333  16.714169
cloud           1048576   1048576   0         127       23.24175   37.179013
sat_zenith      1048576   483728    0.36      0.7       0.466376   0.077153
sun_zenith      1048576   483728    0.87      0.95      0.907019   0.022209
rel_azimuth     1048576   483728    -0.58     -0.33     -0.465731  0.058149
graphics        1048576   1048576   0         14        6.84576    2.931459
```

A.18 cwstatus

Name

cwstatus - shows the status of a CoastWatch data server.

Synopsis

cwstatus [OPTIONS]
cwstatus [OPTIONS] host

Options:

-c, --script=PATH
-h, --help
-s, --splash
-o, --operator

Description

The status utility shows the status of a CoastWatch data server using a graphical user interface. The incoming, unprocessed, processing, and online data are shown and continually updated as the server is processing data. Individual passes with coverage area and preview image may be selected from a list. The status utility is designed for use by research personnel and system operators to monitor a CoastWatch data processing server and select data of interest. Detailed help on the usage of cwstatus is available from within the utility using the menu bar under *Help* | *Help and Support* .

Parameters

Main parameters:

host The CoastWatch server host name. There is no default host name. If specified, the host is contacted and polled for its status immediately after the status utility starts. Otherwise, the user must connect to the server manually using *File* | *New server* on the menu bar.

Options:

-c, --script=PATH ADVANCED USERS ONLY. The query script path. The default is /ctera/query.cgi.

-h, --help Prints a brief help message.

-s, --splash Shows the splash window on startup. The splash window shows the version, author, and web site information.

-o, --operator Specifies that operator messages should be displayed. By default, errors on the server are not of interest to normal users and are not displayed. Operator messages take the form of a special message box that appears when an error occurs.

Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.

Examples

The following command shows the startup of the status monitor for the fictitious server foobar.noaa.gov:

```
phollema@localhost:<~/cwatch/satdata> cwstatus foobar.noaa.gov
```

A.19 hdatt

Name

hdatt - reads or writes HDF file attributes.

Synopsis

hdatt [OPTIONS] input
hdatt {-n, --name=STRING} [OPTIONS] input
hdatt {-n, --name=STRING} {-l, --value=STRING1[/STRING2/...]} [OPTIONS] input

Options:

-h, --help
-t, --type=TYPE
-V, --variable=STRING

Description

The attribute tool reads or writes HDF file attributes using the HDF Scientific Data Sets (SDS) interface. The two modes work as follows:

Read mode In read mode, the tool can read from either the global attribute set (the default), or the attribute set specific to a variable (when then **--variable** option is specified). It can read either all attribute values in the set (the default), or just a single attribute value (when the **--name** option is specified).

Write mode Write mode is specified by the use of the **--value** option, which provides a value for a named attribute. In write mode, the user is required to supply an attribute name and value, and optionally a type. If no type is specified, the type defaults to 'string' (see the **--type** option below for the meanings of various type names). Attributes may be written to the global attribute set (the default), or to specific variables in the data file using the **--variable** option.

Note: The attribute tool is currently limited to reading and writing only the signed HDF data types. In read mode, unsigned HDF attribute data are read correctly, but the value displayed as if it were signed.

Parameters

Main parameters:

-n, --name=STRING The name of the attribute to read or write.

-l, --value=STRING1[/STRING2/...] The value(s) for the named attribute. If specified, this places the tool into write mode, and **--name** must specify an attribute name. If an attribute already exists, its value is overwritten with the new value. If an attribute with the name does not exist, it is created and the new value assigned to it. By default if this option is not used, the tool is in read mode.

input The input data file name.

Options:

-t, --type=TYPE The attribute data type (write mode only). The valid types and their HDF equivalents are as follows:

Type name	HDF type
string	DFNT_CHAR8
byte	DFNT_INT8
short	DFNT_INT16
int	DFNT_INT32
long	DFNT_INT64
float	DFNT_FLOAT32
double	DFNT_FLOAT64

-V, --variable=STRING The variable to read or write the attribute data. By default, the attribute is read from or written to the global attribute set.

Exit status

0 on success, > 0 on failure. Possible causes of errors:

- Invalid command line option.
- Invalid input or output file names.
- Invalid variable name.
- Invalid attribute name in read mode.
- Invalid attribute type in write mode.
- Value does not convert to the specified attribute data type.

Examples

As an example of read mode, the following command reads and prints all the global attribute data from a CoastWatch HDF file:

```
phollema@damdog<~/cwatch/satdata/level3> hdatt 2005_095_1522_n17_er.hdf
satellite = noaa-17
```

```
sensor = avhrr
origin = USDOC/NOAA/NESDIS CoastWatch
cwhdf_version = 3.2
pass_type = day
pass_date = 12878
start_time = 55371.0
projection_type = mapped
projection = Mercator
gctp_sys = 5
gctp_zone = 0
gctp_parm = 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
gctp_datum = 12
et_affine = 0.0 -1470.0 1470.0 0.0 -8804259.100925786 5723777.271647277
rows = 1401
cols = 1302
polygon_latitude = 45.83810150571052 45.83810150571052 45.83810150571052
  45.83810150571052 45.83810150571052 42.51315402540104 38.99999999998719
  35.30179546333813 31.424886223357582 31.424886223357582 31.424886223357582
  31.424886223357582 31.424886223357582 35.30179546333813 38.99999999998719
  42.51315402540104 45.83810150571052
polygon_longitude = -79.09000515710031 -74.79500257855015 -70.5 -66.20499742144985
  -61.90999484289969 -61.90999484289969 -61.90999484289969 -61.90999484289969
  -61.90999484289969 -66.20499742144985 -70.5 -74.79500257855015 -79.09000515710031
  -79.09000515710031 -79.09000515710031 -79.09000515710031 -79.09000515710031
history = cwimport product.tshdf product.hdf
```

To dump only a single attribute:

```
phollema@damdog<~/cwatch/satdata/level3> hdatt --name satellite
  2005_095_1522_n17_er.hdf
noaa-17
```

or a single attribute from a specific variable:

```
phollema@damdog<~/cwatch/satdata/level3> hdatt --name units
  --variable avhrr_ch3a 2005_095_1522_n17_er.hdf
albedo*100%
```

As an example of write mode, suppose that we wanted to save the date when the file was originally downloaded from the server:

```
phollema@damdog<~/cwatch/satdata/level3> hdatt --name download_date
```

```
  --value "Mon Apr 11 18:20:15 PDT 2005" 2005_095_1522_n17_er.hdf
```

Now suppose we wanted to assign an integer quality value of 65% to the file based on some test that was performed on the file data:

```
phollema@damdog<~/cwatch/satdata/level3> hdatt --name quality_value
  --value 65 --type int 2005_095_1522_n17_er.hdf
```

Finally, suppose that we wanted to change the units and scaling factor / offset of a variable, originally in degrees Celsius and scaled by 0.01, to degrees Fahrenheit:

```
phollema@damdog<~/cwatch/satdata/level3> hdatt --name units
  --value "deg F" --variable sst 2005_095_1522_n17_er.hdf
phollema@damdog<~/cwatch/satdata/level3> hdatt --name scale_factor
  --value 0.018 --type double --variable sst 2005_095_1522_n17_er.hdf
phollema@damdog<~/cwatch/satdata/level3> hdatt --name add_offset
  --value -1777.777777 --type double --variable sst
  2005_095_1522_n17_er.hdf
```

Appendix B

CoastWatch HDF Metadata Specification

B.1 Overview

CoastWatch HDF format may be used to store almost any scientific data that has an associated set of Earth locations, including satellite data and output from numerical models. The term *metadata* refers to information describing data. HDF stores metadata as a set of attribute name and value pairs. For example, if a dataset is derived from a satellite called NOAA-16, it is useful to store the attribute name `satellite` and value `noaa-16` along with the data to denote its origin. Along these lines, the CoastWatch metadata standards have been written to help developers write software to read and write data and its associated metadata in a consistent fashion. This document describes the standard and can be used as a reference guide to the HDF attribute names and values in CoastWatch HDF files. A number of overall conventions are used for storing data:

1. Multiple 2D data grids are stored in one HDF file using the HDF Scientific Data Sets (SDS) model. A standard CoastWatch HDF file contains data for one region only.

2. A standard set of global attributes is encoded with the data, describing the date and time, Earth locations, data source or satellite/ sensor, and so on from which the data originated.

3. A standard set of variable attributes is encoded with each variable, describing the variable units, scaling factor, and so on as well as any other important information.

As the requirements for the CoastWatch HDF format evolve, new metadata specifications are added, thus new metadata *versions* support features that older versions do not. An effort is made with each new metadata version to maintain compatibility with older versions:

Version 2.4 The original metadata version supported by the CWF utilities version 2.3 and 2.4 and CDAT 0.6 and 0.7. CoastWatch HDF was originally designed to store projection-mapped satellite data only, and had a very limited set of metadata.

Version 3.1 Support was added for multiple metadata versions, unmapped swath data, per-variable navigational transforms, and the interpretation of the `et_affine` attribute was changed.

Version 3.2 Support was added for non-satellite derived data, composite datasets from multiple time ranges, raster pixel types, region codes and names, temporal extents, vector direction variables, polygon outlines, and various other features.

Version 3.3 Support was added for satellite sensor scan projection type.

Version 3.4 Units strings were standardized to use Unidata UDUNITS style. Vector direction variables now have a convention attribute.

B.2 Global Metadata

The following table lists the standard set of global attributes for CoastWatch HDF:

Attribute name	HDF type	Description	Since version
`cwhdf_version`†	CHAR8	The metadata version. The version is written as a string attribute but should be interpreted as a fractional number, for example 2.3 or 3.1. If absent, version 2.4 is assumed.	3.1
`satellite`‡	CHAR8	If data is from a satellite, the satellite name, for example `noaa-16`, `goes-8`, `orbview-2`.	2.4
	CHAR8	If the data is a composite, multiple values are newline-separated.	3.2
`sensor`‡	CHAR8	If data is from a satellite, the satellite sensor name, for example `avhrr`, `seawifs`.	2.4
	CHAR8	If the data is a composite, multiple values are newline-separated.	3.2
`data_source`‡	CHAR8	If data is not from a satellite, the data source, for example the instrument used to collect the data or the model used to generate the data. If the data is a composite, multiple values are newline-separated.	3.2
`composite`	CHAR8	The composite flag, `true` if the data is derived from multiple datasets, or `false` if not. If true, then the `pass_date`, `start_time`, and `temporal_extent` attributes may contain arrays of values, and the `satellite`, `sensor`, `data_source`, `orbit_type`, `pass_type`, and `origin` attributes may have multiple newline-separated values. If absent, it is assumed that the data is not a composite.	3.2

Attribute name	HDF type	Description	Since version
`pass_date`†	INT32	The date of data recording in days since January 1, 1970.	2.4
	INT32[ ]	If the data is a composite, the dates of data recording in days since January 1, 1970. Date and time data must be stored in sorted order from least recent to most recent.	3.2
`start_time`†	FLOAT64	The start time of the data recording in seconds since 00:00:00 UTC.	2.4
	FLOAT64[ ]	If the data is a composite, the start times of data recording in seconds since 00:00:00 UTC.	3.2
`temporal_extent`	FLOAT64[ ]	The time duration in seconds between the start of data recording and the end of data recording. Multiple values may be present if the data is a composite. If absent, it is assumed that each data recording is instantaneous.	3.2
`pass_type`	CHAR8	The satellite pass temporal type: `day`, `night`, `day/night`.	2.4
	CHAR8	If the data is a composite, multiple values are newline-separated.	3.2
`orbit_type`	CHAR8	If the data is from an orbiting satellite that crosses the equator in a northward or southward direction, the orbit type as `ascending` or `descending` respectively. If the data is a composite, multiple values are newline-separated.	3.2
`origin`†	CHAR8	The original data source as an agency or organization name, for example `USDOC/NOAA/NESDIS CoastWatch`.	2.4
	CHAR8	If the data is a composite, multiple values are newline-separated.	3.2
`history`†	CHAR8	A newline-separated list of utilities and command line parameters used to create the file and perform processing.	2.4

†This attribute is required. Other attributes are optional.
‡Either `satellite` and `sensor`, or `data_source` are required, but not both.

B.3 Earth Location Metadata

In addition to the standard global attributes listed above, a number of Earth location attributes are also present. Prior to version 3.1, only mapped data was supported. For mapped data, all map projection calculations are performed using the General Cartographic Transformation Package (GCTP) from the USGS National Mapping Division. A number of global attributes are dedicated to storing GCTP related parameters. For documentation on the allowed values of GCTP parameters, see section B.6. The table below lists the standard set of global attributes for Earth location metadata:

Attribute name	HDF type	Description	Since version
`projection_type` †	CHAR8	The projection type: `mapped`, `swath`, or `sensor_scan`. Mapped data is formatted to a well-known map projection and accompanied by GCTP map projection parameters. Swath data is data that is not in a standard map projection, but is accompanied by Earth location data for each pixel (see section B.5 on swath data). Sensor scan data is similar to swath in that it cannot be described by a set of map projection parameters, but it can be described by a set of sensor-specific parameters and does not require Earth locations to be stored for each pixel.	3.1
`projection`‡	CHAR8	For mapped data, a descriptive projection name, for example `mercator`, `geographic`, `polar stereographic`.	2.4
`gctp_sys`‡	INT32	For mapped data, the GCTP projection system code.	2.4
`gctp_zone`‡	INT32	For mapped data, the GCTP zone for UTM projections.	2.4
`gctp_parm`‡	FLOAT64[ ]	For mapped data, the GCTP projection parameters (15).	2.4
`gctp_datum`‡	INT32	For mapped data, the GCTP spheroid code.	2.4
`et_affine`‡	FLOAT64[ ]	For mapped data, the map affine transform (6).	2.4
`sensor_code`*	INT32	For sensor scan data, the sensor code. The only code currently available is 0, which indicates a geostationary satellite.	3.3
`sensor_parm`*	FLOAT64[ ]	For sensor scan data, the sensor parameters. For a geostationary satellite (`sensor_code=0`): 1. Subpoint latitude in degrees (geocentric). 2. Subpoint longitude in degrees. 3. Distance of satellite from center of Earth in kilometers. 4. Scan step angle in row direction in radians. 5. Scan step angle in column direction in radians.	3.3
`rows`†	INT32	The number of rows of data.	2.4
`cols`†	INT32	The number of columns of data.	2.4
`polygon_latitude`	FLOAT64[ ]	Latitude components of the bounding polygon with initial element repeated.	3.2
`polygon_longitude`	FLOAT64[ ]	Longitude components of the bounding polygon with initial element repeated.	3.2

Attribute name	HDF type	Description	Since version
`raster_type`	CHAR8	One of `RasterPixelIsArea` or `RasterPixelIsPoint` to capture the same distinction as the GeoTIFF global attribute `GTRasterTypeGeoKey`. If pixels represent point data, then extra SDS variables `latitude` and `longitude` in the dataset localize the point within the pixel area which otherwise defaults to the pixel center. If absent, pixels are assumed to represent area data.	3.2
`region_code`	CHAR8	The data processing region code as a short abbreviation.	3.2
`region_name`	CHAR8	The data processing region name in full.	3.2
`station_code`	CHAR8	The data capture ground station as a short abbreviation.	3.2
`station_name`	CHAR8	The data capture ground station name in full.	3.2

†This attribute is required. Other attributes are optional.
‡Required for mapped data only.
*Required for sensor scan data only.

B.3.1 Version 2 Affine

The `et_affine` attribute is used by CoastWatch software to translate between map (x,y) coordinates in meters and image (row,col) coordinates. GCTP is used to translate between (lat,lon) in degrees and map (x,y) in meters. With this two-step process, the translation between image (row,col) and Earth location (lat,lon) is very flexible and can be expressed partly as a linear coordinate transform. The six affine transform parameters are used in a matrix equation as follows. Let $a..f$ be the `et_affine` attribute array values 0..5, (X, Y) be map coordinate easting and northing in meters, and (R, C) be 1-relative row and column image coordinates, then:

$$\begin{bmatrix} X \\ Y \\ 1 \end{bmatrix} = \begin{bmatrix} a & b & e \\ c & d & f \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} C \\ R \\ 1 \end{bmatrix}$$

or alternatively:

$$\begin{aligned} X &= aC + bR + e \\ Y &= cC + dR + f \end{aligned}$$

The inverse operation may be performed by inverting the affine transform:

$$\begin{aligned} \alpha &= ad - bc \\ a' &= d/\alpha \\ b' &= -b/\alpha \\ c' &= -c/\alpha \\ d' &= a/\alpha \\ e' &= -(a'e + b'f) \\ f' &= -(c'e + d'f) \end{aligned}$$

$$\begin{bmatrix} C \\ R \\ 1 \end{bmatrix} = \begin{bmatrix} a' & b' & e' \\ c' & d' & f' \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X \\ Y \\ 1 \end{bmatrix}$$

or alternatively:

$$\begin{aligned} C &= a'X + b'Y + e' \\ R &= c'X + d'Y + f' \end{aligned}$$

B.3.2 Version 3 Affine

The conventions of the `et_affine` attribute are slightly different in version 3 metadata. The affine transform is stored and used (in matrix form) as:

$$\begin{bmatrix} X \\ Y \\ 1 \end{bmatrix} = \begin{bmatrix} a & c & e \\ b & d & f \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} R \\ C \\ 1 \end{bmatrix}$$

or alternatively:

$$\begin{aligned} X &= aR + cC + e \\ Y &= bR + dC + f \end{aligned}$$

where (R, C) are 0-relative, **not** 1-relative image coordinates. Deriving the inverse transform is similarly changed.

B.4 Variable Metadata

The following table shows the standard set of variable attributes for CoastWatch HDF. Some attribute groups are created by HDF SD convenience functions in order to make data more readable and usable by generic HDF viewing programs. A *<var>* in the *HDF Type* indicates that the attribute type is the same as the variable data type.

Attribute name	HDF type	Description	Since version
`long_name`†	CHAR8	*Written by SDsetdatastrs.* A descriptive variable name, for example `AVHRR channel 4`, `sea surface temperature`.	2.4
`units`†	CHAR8	*Written by SDsetdatastrs.* A descriptive units name in the conventions used by the Unidata UDUNITS package and its supported units file. Many common units are acceptable (and various forms of those units), for example `kelvin`, `celsius` and `fahrenheit` for temperature data, `knots`, `meters per second` or `m/s` for windspeed, `mg per m^-3` or `kg/m-3` for concentration, `percent` or `%` for reflectance, and `degrees` or `radians` for angles.	2.4, updated in 3.4
`format`†	CHAR8	*Written by SDsetdatastrs.* A FORTRAN-77 style format string, for example `F7.2`.	2.4
`coordsys`†	CHAR8	*Written by SDsetdatastrs.* A descriptive coordinate system name, the same as the global `projection` attribute.	2.4
`_FillValue`	<*var*>	*Written by SDsetfillvalue.* The value used to fill in for missing or unwritten data.	2.4
`scale_factor`‡	FLOAT64	*Written by SDsetcal.* The calibration scale factor.	2.4
`scale_factor_err`‡	FLOAT64	*Written by SDsetcal.* The calibration scale error.	2.4
`add_offset`‡	FLOAT64	*Written by SDsetcal.* The calibration offset.	2.4
`add_offset_err`‡	FLOAT64	*Written by SDsetcal.* The calibration offset error.	2.4
`calibrated_nt`‡	INT32	*Written by SDsetcal.* The HDF data type code for uncalibrated data.	2.4
`C_format`†	CHAR8	A C style format string, for example `%7.2f`.	2.4
`missing_value`	<*var*>	The value used to fill in for missing or unwritten data; same as `_FillValue`.	2.4
`fraction_digits`†	INT32	The number of significant digits after the decimal place for calibrated or floating-point variable data. This is an alternative to the C or FORTRAN notation for value formatting and is independent of the programming language.	3.1
`nav_affine`	FLOAT64[ ]	The navigational correction affine transform. If absent, an identity transform is assumed.	3.1
`direction_variable`	CHAR8	The name of the associated SDS variable for vector direction. Any variable with this attribute is assumed to be the magnitude component of a vector field, for which the named variable is the direction component. The direction component is encoded as degrees clockwise from north.	3.2

Attribute name	HDF type	Description	Since version
`direction_convention`	CHAR8	When this SDS variable is the direction component of a vector, the convention for the direction is either `DirectionIsTo` or `DirectionIsFrom` to indicate that the direction indicates where to vectors are pointing to, or pointing from. For example, wind direction is normally quoted as where the wind is coming from, where as ocean currents are quoted as where the current is moving towards. This attribute is only required for direction component SDS variables (see the `direction_variable` attribute).	3.4
`quality_flag`	CHAR8	The name of the associated SDS variable that contains quality flag information.	3.2
`quality_mask`	INT64	The value to use as a mask in a bitwise AND operation to isolate the quality bits in the SDS variable named by the `quality_flag` attribute.	3.2
`flag_bits`	CHAR8	The newline-separated list of flag descriptions for each bit from least significant to most significant. This is generally only required if this SDS variable contains quality flag information for another SDS variable. Any unused bits are denoted by `Unused`.	3.2

† This attribute is required. Other attributes are optional.
‡ Required for calibrated data only.

B.4.1 Calibration Values

The calibration attributes are used to read and write variable data as follows:

$$\begin{array}{lcll} float & = & \texttt{scale\_factor}(int - \texttt{add\_offset}) & \text{(on read)} \\ int & = & float/\texttt{scale\_factor} + \texttt{add\_offset} & \text{(on write)} \end{array}$$

where $float$ and int are the floating-point and integer values respectively. See the HDF User's Guide for more details on data calibration. If no calibration data is found, the data is assumed to be already calibrated.

B.4.2 Navigational Correction

The navigational correction transform has 6 coefficients, similar to the global `et_affine` attribute, and is used (in matrix form) as:

$$\begin{bmatrix} R' \\ C' \\ 1 \end{bmatrix} = \begin{bmatrix} a & c & e \\ b & d & f \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} R \\ C \\ 1 \end{bmatrix}$$

where$a..f$ are the `nav_affine` matrix coefficients in order and (R', C') are the actual image coordinates at which the desired data value for (R, C) may be found.

B.5 Swath Earth Location Encoding

There are currently two methods for specifying Earth location data for CoastWatch HDF swath files:

1. **Explicit encoding:** Two standard 2D HDF SDS variables named `latitude` and `longitude` are written to the file. Each variable must be accompanied with appropriate metadata as outlined above. The latitude and longitude data must not have any values set to the missing or fill value, or problems may occur in performing Earth coordinate transformations.

2. **Polynomial encoding:** A number of 1D HDF SDS variables named *swath_struct*, *swath_bounds*, *swath_lat*, and *swath_lon* are used to define data structures for use in a polynomial approximation algorithm that supports an efficient and accurate estimation of latitude and longitude values for the swath data.

The polynomial encoding option is described in this section. The polynomial approximation scheme is given, along with details on the required HDF variables.

The easiest approach to swath Earth location encoding is to simply record latitude and longitude values for every data value in the swath. For a typical AVHRR swath size of 2048×5000, this can add about 80 Mb of extra data to a file using 32-bit floating point values. To convert a data (row,col) coordinate to geographic (lat,lon) coordinate, an application simply reads the (lat,lon) data at the specified coordinate from the file. This method requires either a large amount of file I/O or a large amount of memory, depending on how much of the Earth location data is read at once. It also does not lend itself to an efficient reverse lookup algorithm for converting an arbitrary (lat,lon) back to (row,col).

In order to support swath data in CoastWatch HDF files but avoid the overhead of storing the Earth locations, a polynomial approximation scheme is used. The approximation scheme also lends itself to an efficient reverse lookup algorithm. The approximation divides the data into a number of rectangular partitions of varying size in rows and columns but bounded physical size in kilometres. For a typical AVHRR swath whose resolution is lowest at the left and right edge of the image data, the rectangular partitioning may look something like Figure B.1.

The approximation derives a set of bivariate polynomials on each partition for latitude and longitude estimation. To convert a (row,col) coordinate to (lat,lon), the partitions are first searched for the one containing the data coordinate. Using the polynomials for that partition, latitude and longitude are calculated for the data coordinate using the polynomial coefficients. By bounding the physical size of each partition, it is possible to bound the error in latitude and longitude estimation. For a typical AVHRR pass, it has been found that a 100 km maximum partition size yields a maximum error of approximately 50 m in Earth location.

The polynomial approximation scheme used is as follows. For each partition, nine latitude and longitude values are sampled in a 3×3 grid pattern as shown in Figure B.2. The (row,col) coordinates and (lat,lon) data values are used to derive two independent sets of 9 polynomial coefficients, one set for latitude and one set for longitude. These coefficients, denoted $a_0..a_8$ and $b_0..b_8$ can be used to recover the latitude and longitude values using the formulae:

$$\begin{aligned} lat(x,y) &= a_0 + a_1x + a_2x^2 + a_3y + a_4xy + a_5x^2y + a_6y^2 + a_7xy^2 + a8x^2y^2 \\ lon(x,y) &= b_0 + b_1x + b_2x^2 + b_3y + b_4xy + b_5x^2y + b_6y^2 + b_7xy^2 + b_8x^2y^2 \end{aligned}$$

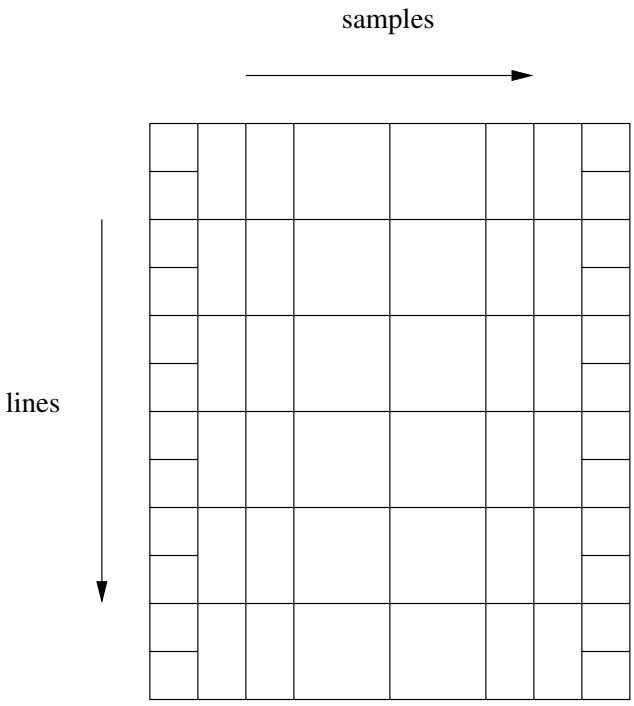


Figure B.1: A partitioning of AVHRR swath data. Each partition has a bounded physical size in the lines and samples directions.

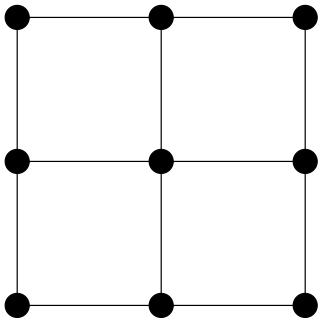


Figure B.2: Sampling pattern for polynomial approximation. Each • symbol is a sampling point for latitude and longitude.

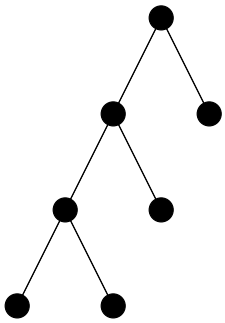


Figure B.3: Binary tree encoding example. The tree is encoded under a preorder traversal by the binary string `000111`.

where x is the image row and y is the image column. Note that the polynomial approximation also acts to interpolate (lat,lon) coordinates between integer data coordinates, since there are no requirements on x and y to be integers in the above equations. This is important for the accuracy of the reverse-lookup algorithm described later.

Since each partition is associated with its own set of coefficients, a simple algorithm to search for the appropriate partition for a data (row,col) coordinate is to loop through all partitions, checking the row and column bounds on each partition until one containing the desired (row,col) coordinate is found. If there are n partitions, then the loop will perform $O(n)$ (where $O()$ denotes an *order of* upper bound relationship) partition bound checks. In order to avoid this, a binary tree is used to arrange the partitions in a hierarchical structure. The set of partitions with polynomial coefficients form the leaves of the tree. The relationship between parent and child nodes is such that each child is a binary sub-partition of the parent. In this way, a search through n partitions is replaced by a search down the binary tree through $O(\log n)$ partitions until a leaf is encountered. For encoding purposes, a binary tree structure may be encoded uniquely using a preorder traversal of its nodes. A `0` is used to encode a left child, and a `1` for a right child (the root is not recorded because we assume that the preorder traversal starts at the root). Figure B.3 shows the binary tree for the encoding `000111`. A more complex example in Figure B.4 show the binary tree for the encoding `000111001101`.

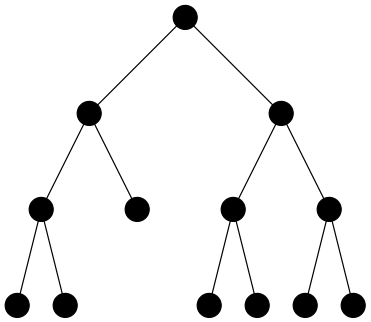


Figure B.4: A more complex binary tree encoding example. The tree is encoded under a preorder traversal by the binary string `000111001101`.

For a complete encoding of the swath including the polynomial coefficients for each leaf partition, all partition boundaries, and the binary tree structure, the following HDF variables are used:

Variable name	HDF type	Description
`swath_struct`	INT8	A preorder encoding of the binary tree. The encoding bits are zero-padded at the end to the nearest byte.
`swath_bounds`	FLOAT64	Upper-left and lower-right (row,col) bounds for each partition. All partition bounds are recorded, including all leaf and non-leaf partitions in the tree.
`swath_lat`	FLOAT64	Latitude polynomial coefficients for each leaf partition. There are 9 coefficients stored for each partition.
`swath_lon`	FLOAT64	Longitude polynomial coefficients for each leaf partition. There are 9 coefficients stored for each partition.

This encoding may be used to re-create the tree structure and populate the tree with partition bound and polynomial information. For a typical AVHRR pass which might require 80 Mb of data if all (lat,lon) coordinates were pre-computed, this encoding only requires about 500 kb using a maximum partition size of 100 km.

Finally, the reverse-lookup algorithm to convert (lat,lon) coordinates back to (row,col) is as follows. Define the following symbols:

Let T be a tolerance distance in kilometers.
Let $\overrightarrow{C}_g^{in}$ be the input geographic (lat,lon) coordinate.
Let $\overrightarrow{C}_d^{out}$ be the output data (row,col) coordinate.
Let $D_{\overrightarrow{C}_g}(\overrightarrow{C}_d)$ be a function that computes the physical distance in kilometers between geographic coordinate $\overrightarrow{C}_g$ and data coordinate $\overrightarrow{C}_d$.
Let N_r and N_c be the total number of rows and columns.
Let $\overrightarrow{\nabla}_d$ be the gradient operator in data coordinates, $\overrightarrow{\nabla}_d = (\frac{\partial}{\partial r}, \frac{\partial}{\partial c})$.

Now, initialize $\overrightarrow{C}_d^{out}$ and iterate until the tolerance is satisfied:

$\overrightarrow{C}_d^{out} = (N_r/2, N_c/2)$
$d = D_{\overrightarrow{C}_g^{in}}(\overrightarrow{C}_d^{out})$
while $d > T$ {
  $\overrightarrow{u} = \overrightarrow{\nabla}_d D_{\overrightarrow{C}_g}(\overrightarrow{C}_d)$
  $\hat{u} = \overrightarrow{u}/|\overrightarrow{u}|$
  $\overrightarrow{C}_d^{out} = \overrightarrow{C}_d^{out} - d\hat{u}$
  $d = D_{\overrightarrow{C}_g^{in}}(\overrightarrow{C}_d^{out})$
}

This algorithm is particularly well suited to be used with a polynomial approximation scheme for (lat,lon) because it can provide sub-pixel accuracy in the (row,col) coordinate. For example as part of a data resampling algorithm, once a fractional data coordinate is obtained for a given (lat,lon), nearest neighbour or bilinear interpolation may then be used to provide a smooth data resampling.

B.6 GCTP Appendices

```
Function Description
********************

gctp - Initializes projection transformation parameters and performs
transformations.

SYNTAX

  FUNCTION gctp (incoor, insys, inzone, inparm, inunit, indatum, ipr,
  efile, jpr, pfile, outcoor, outsys, outzone, outparm, outunit,
  outdatum, fn27, fn83, iflg)

  double incoor[2];
  long *insys;
  long *inzone;
  double inparm[15];
  long *inunit;
  long *indatum;
  long *ipr;
  char efile[];
  long *jpr;
  char pfile[];
  double outcoor[2];
  long *outsys;
```

```
  long *outzone;
  double outparm[15];
  long *outunit;
  long *outdatum;
  char fn27[];
  char fn83[];
  long *iflg;

PARAMETERS

* incoor (input, double, length(2))

  Array of two input coordinates (X-Y, Longitude-Latitude,
  Northing-Easting, etc) to be translated. The nature of the
  coordinates is defined by insys, inzone, and inunit. The east-west
  dimension (X, Longitude, Easting) is first followed by the
  north-south (Y, latitude, Northing).

* insys (input, long)

  Defines the input projection system. Valid codes are:
  = 0: GEO (Geographic)
  = 1: UTM (Universal Transverse Mercator)
  = 2: SPCS (State Plane Coordinates)
  = 3: ALBERS (Albers Conical Equal Area)
  = 4: LAMCC (Lambert Conformal Conic)
  = 5: MERCAT (Mercator)
  = 6: PS (Polar Stereographic)
  = 7: POLYC (Polyconic)
  = 8: EQUIDC (Equidistant Conic)
  = 9: TM (Transverse Mercator)
  = 10: STEREO (Stereographic)
  = 11: LAMAZ (Lambert Azimuthal Equal Area)
  = 12: AZMEQD (Azimuthal Equidistant)
  = 13: GNOMON (Gnomonic)
  = 14: ORTHO (Orthographic)
  = 15: GVNSP (General Vertical Near-Side Perspective)
  = 16: SNSOID (Sinusoidal)
  = 17: EQRECT (Equirectangular)
  = 18: MILLER (Miller Cylindrical)
  = 19: VGRINT (Van der Grinten)
  = 20: HOM (Hotine Oblique Mercator--HOM)
  = 21: ROBIN (Robinson)
  = 22: SOM (Space Oblique Mercator--SOM)
  = 23: ALASKA (Modified Stereographic Conformal--Alaska)
  = 24: GOOD (Interrupted Goode Homolosine)
  = 25: MOLL (Mollweide)
  = 26: IMOLL (Interrupted Mollweide)
```

```
  = 27: HAMMER (Hammer)
  = 28: WAGIV (Wagner IV)
  = 29: WAGVII (Wagner VII)
  = 30: OBLEQA (Oblated Equal Area)

* inzone (input, long)

  Input zone for UTM and State Plane projection systems. The UTM
  Coordinate System (insys = 1) and State Plane Coordinate System
  (insys = 2) use zone codes instead of specific projection parameters
  (See Appendix B--UTM and Appendix C--State Plane). For Southern
  Hemisphere UTM, use a negative zone code. Inzone will be ignored for
  all other projections.

* inparm (input, double, length(15))

  Array of fifteen projection parameters. These parameters are
  required to define each map projection.  (See Appendix A)

* inunit (input, long)

  Unit code for input coordinates. Valid unit codes are:
  = 0: radians
  = 1: U.S. feet
  = 2: meters
  = 3: seconds of arc
  = 4: degrees of arc
  = 5: International feet
  = 6: Table supplying the unit code, which is legislated
       for the State zone selected

* indatum (input, long)

  Input spheroid code. This identifies the semi-major axis and
  eccentricity that is to be used in the transformation process. If a
  negative spheroid code is entered, inparm elements 1 and 2 are to be
  used (See Appendix A). Supported spheroids include:
  = 0: Clarke 1866 (default)
  = 1: Clarke 1880
  = 2: Bessel
  = 3: International 1967
  = 4: International 1909
  = 5: WGS 72
  = 6: Everest
  = 7: WGS 66
  = 8: GRS 1980
  = 9: Airy
  = 10: Modified Everest
```

```
  = 11: Modified Airy
  = 12: WGS 84
  = 13: Southeast Asia
  = 14: Australian National
  = 15: Krassovsky
  = 16: Hough
  = 17: Mercury 1960
  = 18: Modified Mercury 1968
  = 19: Sphere of Radius 6370997 meters

  Note: State Plane projection (insys = 2) only supports Clarke 1866
  (indatum = 0) and GRS 1980 (indatum = 8) spheroids corresponding to
  datums NAD27 and NAD83 respectively (See Appendix B).

* ipr (input, long)

  Error message print flag. If ipr is zero, error messages will be
  printed to the terminal. If ipr is one, error messages will be
  printed to efile. If ipr is two, error messages will be printed to
  both the terminal and efile. If ipr is something else, error
  messages will not be printed.

* efile (input, character, length(*))

  The file which will contain the output error messages. efile need
  not be opened at this time.

* jpr (input, long)

  Projection parameter print flag. If jpr is zero, projection
  parameters will be printed to the terminal. If jpr is one,
  projection parameters will be printed to pfile. If jpr is two,
  projection parameters will be printed to both the terminal and
  pfile. If jpr is something else, the projection parameters will not
  be printed. As specified by jpr, Projection parameters are printed
  each time the input projection parameters (insys, inzone, inparm,
  inunit, indatum, outsys, outzone, outparm, outunit, and outdatum)
  change.

* pfile (input, character, length(*))

  The file which will contain the output projection parameter
  messages. pfile need not be opened at this time.

* outcoor (output, double, length(2))

  Array of two transformed coordinates. See incoor for an explanation.
```

```
* outsys (input, long)

  Defines the output projection system. See insys.

* outzone (input, long)

  Output zone for UTM and State Plane projection systems. The UTM
  Coordinate System (outsys = 1) and State Plane Coordinate System
  (outsys = 2) use zone codes instead of specific projection
  parameters (See Appendix B--UTM and Appendix C--State Plane). For
  Southern Hemisphere UTM, use a negative zone code. Outzone will be
  ignored for all other projections.

* outparm (input, double, length(15))

  Array of fifteen projection parameters. These parameters are
  required to define each map projection.  (See Appendix A)

* outunit (input, long)

  Unit code for output coordinates. See inunit.

* outdatum (input, long)

  Output spheroid code. See indatum.

* fn27 (input, character, length(*))

  Name of the file which contains the NAD 1927 State Plane zone
  parameters.

* fn83 (input, character, length(*))

  Name of the file which contains the NAD 1983 State Plane zone
  parameters.

* iflg (output, long)

  Error flag after transformation. The error number returned will
  correspond to the specific error.

DESCRIPTION

  This routine initializes the proper projection parameters when
  initialization is required. The proper informational and error
  message handling is initialized. Then, the incoor coordinates are
  converted from the insys map projection to the outsys map projection
  and are returned in outcoor.
```

```
RETURN VALUE

  gctp() has no return value.


Projection Transformation Package Projection Parameters
*******************************************************
```

Code & Projection Id	Array Element							
	1	2	3	4	5	6	7	8
0 Geographic								
1 U T M	Lon/Z	Lat/Z						
2 State Plane								
3 Albers Equal Area	SMajor	SMinor	STDPR1	STDPR2	CentMer	OriginLat	FE	FN
4 Lambert Conformal C	SMajor	SMinor	STDPR1	STDPR2	CentMer	OriginLat	FE	FN
5 Mercator	SMajor	SMinor			CentMer	TrueScale	FE	FN
6 Polar Stereographic	SMajor	SMinor			LongPol	TrueScale	FE	FN
7 Polyconic	SMajor	SMinor			CentMer	OriginLat	FE	FN
8 Equid. Conic A	SMajor	SMinor	STDPAR		CentMer	OriginLat	FE	FN
Equid. Conic B	SMajor	SMinor	STDPR1	STDPR2	CentMer	OriginLat	FE	FN
9 Transverse Mercator	SMajor	SMinor	Factor		CentMer	OriginLat	FE	FN
10 Stereographic	Sphere				CentLon	CenterLat	FE	FN
11 Lambert Azimuthal	Sphere				CentLon	CenterLat	FE	FN
12 Azimuthal	Sphere				CentLon	CenterLat	FE	FN
13 Gnomonic	Sphere				CentLon	CenterLat	FE	FN
14 Orthographic	Sphere				CentLon	CenterLat	FE	FN
15 Gen. Vert. Near Per	Sphere		Height		CentLon	CenterLat	FE	FN
16 Sinusoidal	Sphere				CentMer		FE	FN
17 Equirectangular	Sphere				CentMer	TrueScale	FE	FN
18 Miller Cylindrical	Sphere				CentMer		FE	FN
19 Van der Grinten	Sphere				CentMer	OriginLat	FE	FN
20 Hotin Oblique Merc A	SMajor	SMinor	Factor			OriginLat	FE	FN
Hotin Oblique Merc B	SMajor	SMinor	Factor	AziAng	AzmthPt	OriginLat	FE	FN
21 Robinson	Sphere				CentMer		FE	FN
22 Space Oblique Merc A	SMajor	SMinor		IncAng	AscLong		FE	FN
Space Oblique Merc B	SMajor	SMinor	Satnum	Path			FE	FN
23 Alaska Conformal	SMajor	SMinor					FE	FN
24 Interrupted Goode	Sphere							
25 Mollweide	Sphere				CentMer		FE	FN
26 Interrupt Mollweide	Sphere							
27 Hammer	Sphere				CentMer		FE	FN
28 Wagner IV	Sphere				CentMer		FE	FN
29 Wagner VII	Sphere				CentMer		FE	FN
30 Oblated Equal Area	Sphere		Shapem	Shapen	CentLon	CenterLat	FE	FN

Array elements 9-15 Continued on page 2

Projection Transformation Package Projection Parameters elements 9-15
continued from page 1:

Code & Projection Id	Array Element 9	10	11	12	13
0 Geographic					
1 U T M					
2 State Plane					
3 Albers Equal Area					
4 Lambert Conformal C					
5 Mercator					
6 Polar Stereographic					
7 Polyconic					
8 Equid. Conic A	zero				
Equid. Conic B	one				
9 Transverse Mercator					
10 Stereographic					
11 Lambert Azimuthal					
12 Azimuthal					
13 Gnomonic					
14 Orthographic					
15 Gen. Vert. Near Per					
16 Sinusoidal					
17 Equirectangular					
18 Miller Cylindrical					
19 Van der Grinten					
20 Hotin Oblique Merc A	Long1	Lat1	Long2	Lat2	zero
Hotin Oblique Merc B					one
21 Robinson					
22 Space Oblique Merc A	PSRev	LRat	PFlag		zero
Space Oblique Merc B					one
23 Alaska Conformal					
24 Interrupted Goode					
25 Mollweide					
26 Interrupt Mollweide					
27 Hammer					
28 Wagner IV					
29 Wagner VII					

```
   30 Oblated Equal Area   |Angle|    |     |    |    |
   ---------------------------------------------------
```

where

Lon/Z	Longitude of any point in the UTM zone or zero. If zero, a zone code must be specified.
Lat/Z	Latitude of any point in the UTM zone or zero. If zero, a zone code must be specified.
SMajor	Semi-major axis of ellipsoid. If zero, Clarke 1866 in meters is assumed.
SMinor	Eccentricity squared of the ellipsoid if less than zero, if zero, a spherical form is assumed, or if greater than zero, the semi-minor axis of ellipsoid.
Sphere	Radius of reference sphere. If zero, 6370997 meters is used.
STDPAR	Latitude of the standard parallel
STDPR1	Latitude of the first standard parallel
STDPR2	Latitude of the second standard parallel
CentMer	Longitude of the central meridian
OriginLat	Latitude of the projection origin
FE	False easting in the same units as the semi-major axis
FN	False northing in the same units as the semi-major axis
TrueScale	Latitude of true scale
LongPol	Longitude down below pole of map
Factor	Scale factor at central meridian (Transverse Mercator) or center of projection (Hotine Oblique Mercator)
CentLon	Longitude of center of projection
CenterLat	Latitude of center of projection
Height	Height of perspective point
Long1	Longitude of first point on center line (Hotine Oblique Mercator, format A)
Long2	Longitude of second point on center line (Hotine Oblique Mercator, format A)
Lat1	Latitude of first point on center line (Hotine Oblique Mercator, format A)
Lat2	Latitude of second point on center line (Hotine Oblique Mercator, format A)
AziAng	Azimuth angle east of north of center line (Hotine Oblique Mercator, format B)
AzmthPt	Longitude of point on central meridian where azimuth occurs (Hotine Oblique Mercator, format B)
IncAng	Inclination of orbit at ascending node, counter-clockwise from equator (SOM, format A)
AscLong	Longitude of ascending orbit at equator (SOM, format A)
PSRev	Period of satellite revolution in minutes (SOM, format A)
LRat	Landsat ratio to compensate for confusion at northern end of orbit (SOM, format A -- use 0.5201613)
PFlag	End of path flag for Landsat: 0 = start of path,

```
                1 = end of path (SOM, format A)
      Satnum    Landsat Satellite Number (SOM, format B)
      Path      Landsat Path Number (Use WRS-1 for Landsat 1, 2 and 3 and
                WRS-2 for Landsat 4, 5 and 6.)  (SOM, format B)
      Shapem    Oblated Equal Area oval shape parameter m
      Shapen    Oblated Equal Area oval shape parameter n
      Angle     Oblated Equal Area oval rotation angle

                                  NOTES

   Array elements 14 and 15 are set to zero
   All array elements with blank fields are set to zero
   All angles (latitudes, longitudes, azimuths, etc.) are entered in packed
        degrees/ minutes/ seconds (DDDMMMSSS.SS) format



   The following notes apply to the Space Oblique Mercator A projection.

      A portion of Landsat rows 1 and 2 may also be seen as parts of rows
   246 or 247.  To place these locations at rows 246 or 247, set the end of
   path flag (parameter 11) to 1--end of path.  This flag defaults to zero.

      When Landsat-1,2,3 orbits are being used, use the following values
   for the specified parameters:

      Parameter 4   099005031.2
      Parameter 5   128.87 degrees - (360/251 * path number) in packed
    DMS format
      Parameter 9   103.2669323
      Parameter 10  0.5201613

      When Landsat-4,5 orbits are being used, use the following values
   for the specified parameters:

      Parameter 4   098012000.0
      Parameter 5   129.30 degrees - (360/233 * path number) in packed
    DMS format
      Parameter 9   98.884119
      Parameter 10  0.5201613


UTM Zone Codes
**************

The Universal Transverse Mercator (UTM) Coordinate System uses zone codes
instead of specific projection parameters.  The table that follows lists
```

UTM zone codes as used by GCTPc Projection Transformation Package.

Zone	C.M.	Range	Zone	C.M.	Range
01	177W	180W-174W	31	003E	000E-006E
02	171W	174W-168W	32	009E	006E-012E
03	165W	168W-162W	33	015E	012E-018E
04	159W	162W-156W	34	021E	018E-024E
05	153W	156W-150W	35	027E	024E-030E
06	147W	150W-144W	36	033E	030E-036E
07	141W	144W-138W	37	039E	036E-042E
08	135W	138W-132W	38	045E	042E-048E
09	129W	132W-126W	39	051E	048E-054E
10	123W	126W-120W	40	057E	054E-060E
11	117W	120W-114W	41	063E	060E-066E
12	111W	114W-108W	42	069E	066E-072E
13	105W	108W-102W	43	075E	072E-078E
14	099W	102W-096W	44	081E	078E-084E
15	093W	096W-090W	45	087E	084E-090E
16	087W	090W-084W	46	093E	090E-096E
17	081W	084W-078W	47	099E	096E-102E
18	075W	078W-072W	48	105E	102E-108E
19	069W	072W-066W	49	111E	108E-114E
20	063W	066W-060W	50	117E	114E-120E
21	057W	060W-054W	51	123E	120E-126E
22	051W	054W-048W	52	129E	126E-132E
23	045W	048W-042W	53	135E	132E-138E
24	039W	042W-036W	54	141E	138E-144E
25	033W	036W-030W	55	147E	144E-150E
26	027W	030W-024W	56	153E	150E-156E
27	021W	024W-018W	57	159E	156E-162E
28	015W	018W-012W	58	165E	162E-168E
29	009W	012W-006W	59	171E	168E-174E
30	003W	006W-000E	60	177E	174E-180W

Obtained from Software Documentation for GCTP General Cartographic Transformation Package: National Mapping Program Technical Instructions, U.S. Geological Survey, National Mapping Division, Oct 1990,

Note: The following source contains UTM zones plotted on a world map:

Snyder, John P. Map Projections--A Working Manual: U.S. Geological Survey Professional Paper 1395 (Supersedes USGS Bulletin 1532), United States Government Printing Office, Washington D.C. 1987. p. 42.

State Plane Zone Codes
****

State Plane Coordinate System uses zone codes instead of specific projection parameters. The table that follows lists State Plane zone codes as used by the GCTPc Projection Transformation Package.

Jurisdiction Zone name or number	Zone Code	Zone Code
Alabama		
East	0101	0101
West	0102	0102
Alaska		
01 through 10	5001	5001
thru	5010	5010
Arizona		
East	0201	0201
Central	0202	0202
West	0203	0203
Arkansas		
North	0301	0301
South	0302	0302
California		
01 through 07	0401	0401
thru	0407	0406
Colorado		
North	0501	0501
Central	0502	0502
South	0503	0503
Connecticut	0600	0600
Delaware	0700	0700
District of Columbia	1900	1900
Florida		
East	0901	0901
West	0902	0902
North	0903	0903
Georgia		
East	1001	1001
West	1002	1002
Hawaii		
01 through 05	5101	5101
thru	5105	5105
Idaho		
East	1101	1101
Central	1102	1102

West	1103	1103
Illinois		
East	1201	1201
West	1202	1202
Indiana		
East	1301	1301
West	1302	1302
Iowa		
North	1401	1401
South	1402	1402
Kansas		
North	1501	1501
South	1502	1502
Kentucky		
North	1601	1601
South	1602	1602
Louisiana		
North	1701	1701
South	1702	1702
Offshore	1703	1703
Maine		
East	1801	1801
West	1802	1802
Maryland	1900	1900
Massachusetts		
Mainland	2001	2001
Island	2002	2002
Michigan		
East(TM)	2101	----
Central(TM)	2102	----
West(TM)	2103	----
North(Lam)	2111	2111
Central(Lam)	2112	2112
South(Lam)	2113	2113
Minnesota		
North	2201	2201
Central	2202	2202
South	2203	2203
Mississippi		
East	2301	2301
West	2302	2302
Missouri		
East	2401	2401
Central	2402	2402
West	2403	2403
Montana	----	2500
North	2501	----
Central	2502	----

South	2503	----
Nebraska	----	2600
North	2601	----
South	2602	----
Nevada		
East	2701	2701
Central	2702	2702
West	2703	2703
New Hampshire	2800	2800
New Jersey	2900	2900
New Mexico		
East	3001	3001
Central	3002	3002
West	3003	3003
New York		
East	3101	3101
Central	3102	3102
West	3103	3103
Long Island	3104	3104
North Carolina	3200	3200
North Dakota		
North	3301	3301
South	3302	3302
Ohio		
North	3401	3401
South	3402	3402
Oklahoma		
North	3501	3501
South	3502	3502
Oregon		
North	3601	3601
South	3602	3602
Pennsylvania		
North	3701	3701
South	3702	3702
Rhode Island	3800	3800
South Carolina	----	3900
North	3901	----
South	3902	----
South Dakota		
North	4001	4001
South	4002	4002
Tennessee	4100	4100
Texas		
North	4201	4201
North Central	4202	4202
Central	4203	4203
South Central	4204	4204

South	4205	4205
Utah		
North	4301	4301
Central	4302	4302
South	4303	4303
Vermont	4400	4400
Virginia		
North	4501	4501
South	4502	4502
Washington		
North	4601	4601
South	4602	4602
West Virginia		
North	4701	4701
South	4702	4702
Wisconsin		
North	4801	4801
Central	4802	4802
South	4803	4803
Wyoming		
East	4901	4901
East Central	4902	4902
West Central	4903	4903
West	4904	4904
Puerto Rico	5201	5200
Virgin Islands	----	5200
St. John, St. Thomas	5201	----
St. Croix	5202	----
American Samoa	5300	----
Guam	5400	----

Obtained from Software Documentation for GCTP General Cartographic Transformation Package: National Mapping Program Technical Instructions, U.S. Geological Survey, National Mapping Division, Oct 1990,

Note: Equations for State Plane zones are given in:

> Clarie, Charles N, State Plane Coordinates by Automatic Data Processing, U.S. Department of Commerce, Environmental Science Services Administration, Coast and Geodetic Survey, United States Government Printing Office, Publication 62-4, 1973.

Appendix C

Data Format Compatibility

Many of the tools automatically detect the input file format and perform the same operation for a number of different formats, for example CoastWatch IMGMAP files and CoastWatch HDF files. The following table shows the file format compatibility of the various tools:

Tool	Input formats	Output formats
cdat	CWHDF/NC, CWF, TSHDF, N1B, OPeNDAP	CWHDF, Binary, Text, ArcGIS, PNG, GIF, JPEG, PDF, GeoTIFF
cwangles	CWHDF/NC	–
cwautonav	CWHDF/NC, CWF	–
cwcomposite	CWHDF/NC, CWF, TSHDF, OPeNDAP	CWHDF
cwcoverage	CWHDF/NC, CWF, TSHDF, N1B, OPeNDAP	PNG
cwdownload	–	–
cwexport	CWHDF/NC, CWF, TSHDF, N1B, OPeNDAP	Binary, Text, ArcGIS
cwgraphics	CWHDF/NC, CWF, TSHDF, N1B, OPeNDAP	CWHDF
cwimport	CWHDF/NC, CWF, TSHDF, N1B, OPeNDAP	CWHDF
cwinfo	CWHDF/NC, CWF, TSHDF, N1B, OPeNDAP	–
cwmaster	CWHDF/NC, CWF, TSHDF	CWHDF
cwmath	CWHDF/NC, CWF, TSHDF, N1B, OPeNDAP	CWHDF
cwnavigate	CWHDF/NC	–
cwregister	CWHDF/NC, CWF, TSHDF, N1B, OPeNDAP	CWHDF

Tool	Input formats	Output formats
cwrender	CWHDF/NC, CWF, TSHDF, N1B, OPeNDAP	PNG, GIF, JPEG, PDF, GeoTIFF
cwsample	CWHDF/NC, CWF, TSHDF, N1B, OPeNDAP	Text
cwstats	CWHDF/NC, CWF, TSHDF, N1B, OPeNDAP	–
cwstatus	–	–

where:

CWHDF/NC HDF 4 and netCDF 3 with CoastWatch HDF or CF metadata (.hdf, .nc). CF metadata support is still experimental.

CWF CoastWatch format (.cwf) files that contain AVHRR SST, cloud, channel, angle, and graphics data. These files were produced by CoastWatch up to 2004.

TSHDF SeaSpace TeraScan files that have been converted to HDF using tdftohdf. Only the `rectangular`, `polarstereo`, `mercator`, and `emercator` projections are supported, along with `sensor_scan` if latitude and longitude angles have been included in the file.

N1B NOAA 1b AVHRR data, format versions 1 through 5, GAC or LAC resolutions, 8-bit, 10-bit, and 16-bit sensor word sizes with or without archive header.

OPeNDAP OPeNDAP datasets with CoastWatch HDF or CF metadata, map projection files only. CF metadata support is still experimental. Swath datasets and `RasterPixelIsPoint` mode are not supported.

Binary Raw binary format. See individual manual pages for a description of the binary file contents.

Text Standard ASCII text format. See individual manual pages for a description of the text file contents.

ArcGIS ESRI ArcGIS binary grid format (32-bit IEEE floats) with accompanying header file.

PNG Portable Network Graphics with optional world file.

GIF Graphics Interchange Format with optional world file.

JPEG Joint Photographic Experts Group with optional world file.

PDF Adobe Portable Document Format

GeoTIFF Tagged Image File Format with georeferencing tags.

Appendix D

History of Changes

Version 1, 1997/10/01 (internal release)

Version 2, 1998/09/09 (first public release)

Version 2.2, 1999/01/19

- cwf.c:
  Fixed file close bug in decompression routine
  Added more NOAA satellite codes (NOAA-15, -16, -17)
- Created composite program, cwfcomp
- cwftoarc.c:
  Corrected lower-left pixel position and cell size
  Added binary output option
  Added polar projection conversion
  Added projection specifications note
- cwftogif.c:
  Changed IR default min
  Changed brightness temperature legend
- cwproj.c:
  Modified polar projection calculation for Alaska file bugs

Version 2.3, 1999/10/18

- cwfcomp.c:
  Added -b option to allow badval specification

Changed output file date to match last file

- cwf.c:
  Added f to various float constants
  Added test for near-zero IR values
  Simplified round function
  Fixed bug in cw_compress for files with cols < 512
  Added calibration guess for older WCRN files
- cwfnav.c:
  Fixed usage message
- cwftogif.c cwftohdf.c cwftonc.c cwftoraw.c cwfval.c cwproj.c:
  Simplified round function
- cwproj.c:
  Added corrections for WCRN's linear files
- cwftogif.c:
  Modified graphics plane layering, reformatted and commented
  Added ramsdis color palette for CH4 IR
- cwftohdf.c: Completely rewritten
- Created new HDF information routine: hdfinfo
- Created new landmasking routine, cwflmask
- Updated Makefile for new HDF and netCDF releases

Version 2.4, 2001/06/21 (internal release)

- Changed Makefile to include cwproj.c in libcwf.a
- Created cwflmaskdb routine
- cwproj.c: Modified for linear lat/lon header errors
- Fixed hdfinfo and cwftohdf usage messages
- cwf.c: Added orbit_type "both" and channel_number "sst_multi"
- cwftohdf.c: Added orbit_type "both" and channel_number "sst_multi"
- cwf.c: Added flat file support, reading only
- Moved cwftohdf to cwftocwhdf
- Moved hdfinfo to cwhdfinfo
- Fixed CWclone bug in hcwf library
- Added Julian day printing to cwhdfinfo

Version 3.1.0, 2001/07/19

- Implemented in Java using Java native interface to CWF and GCTP code.
- Now uses HDF4 via the HDF JNI calls.
- Now supports swath data.

Version 3.1.1, 2002/10/17

- Added rendering.
- Compiled shared libraries for Windows and Solaris.

Version 3.1.2, 2002/12/30

- Optimized coordinate translation code, rendering now runs 20% faster.
- Modified rendering normalization for viewable data only.
- Added grid overlay label drop shadows for better label legibility.
- Removed miter problems in shape drawings and coast lines.
- Added gridded dataset tile read/write caching for improved memory performance.
- Added NDVI palette.
- Corrected bitmask rendering for PDF files.
- Added registration tool for mapping between projections.
- Added generic bitmask rendering.
- Added navigation, master, sampling tools.
- Modified download tool command line parameters for regular expression matching.
- Added angle calculation tool.
- Improved coastline selection and rendering performance using binned GMT HDF dataset.

Version 3.1.3, 2003/03/31

- Added new tool for server status monitoring.
- Optimized download and status tools for database usage and updated command line options.
- Added GeoTIFF output for mapped projection data to cwrender.

- Added NOAA 1b GAC/LAC AVHRR input.
- Fixed various bugs and made performance improvements.
- Updated Unix startup script for headless operations.

Version 3.1.4, 2003/05/16

- Added two new tools: cwmath and cwcomposite.
- Added MacOS X support in the dynamic JNI libraries and wrapper script.
- Fixed dateline crossing navigation problems in NOAA 1b readers – still needs refinement for near-polar areas.
- Added basic GSHHS polygon rendering code to BinnedGSHHSReader – still needs refinement for bin boundaries and polygons broken by projection distortion.
- Added support for rendering progress to EarthDataView in preparation for CDAT operations.
- Added GLERL palettes "GLERL-Archive" and "GLERL-30-Degrees" palettes to the rendering tool and "NDVI" palette.
- Added "--age" option to download tool for specifying the desired maximum age of the data in hours.
- Added file chooser filters for ".hdf" and ".cwf" files in the cwmaster tool for easier use.
- Added 3D logos to rendering output.

Version 3.1.5, 2003/09/03

- Extended GeoTIFF output in cwrender to generate a paletted file when no overlays are used, and such that the ImageDescription TIFF tag contains a mapping equation from palette index to data value.
- Corrected cwimport so that the "pass_type" attribute is correctly written when the metadata version is < 3.
- Corrected the text output from cwexport to write "NaN" for invalid values.
- Corrected a 0.5 pixel offset problem in image overlay rendering.
- Added land polygon filling algorithms for cwmaster (by default) and cwrender (by using --coast).
- Added --operator option in cwstatus for verbose operator messages.
- Added bitwise or/and functions in cwmath.
- Added new "cwgraphics" tool to generate standard CoastWatch graphics overlays.
- Modified cwdownload to more gracefully handle connection errors and network timeouts.

Version 3.1.6, 2003/12/06

- Fixed space in resource path problem in Windows.
- Added support for AIX and IRIX.
- Added a resize bar for cwstatus between the online data list and data coverage / data preview panels.
- Added the cwcoverage tool for showing region coverage plots (need to add ground station coverage circle feature).

Version 3.1.7, 2004/06/19

- Updated TeraScan HDF import for equirectangular projections and spheroid detection.
- Changed EarthVectorReader to EarthVectorSource.
- Moved file path creation to IOServices.
- Created ContourGenerator and TopographyOverlay classes and added contouring to cwrender.
- Changed command line tools to split multi-parameter options on regular expression, including ',' and '/'.
- Added splash screen for cwmaster and cwstatus.
- Added support in CWHDFReader for explicit lat/lon data rather than polynomial coefficients.
- Changed use of Vector in many classes to ArrayList for better performance.
- Added support for unsigned HDF and CWF variable data.
- Modified data color scale in cwrender for better log scale behaviour.
- Modified cwmaster and cwstatus batch files to run with the Windows look and feel.
- Fixed automatic center calculation problem in cwcoverage.
- Fixed rounding problem in EarthDataViewPanel.TrackBar.
- Added build file for ant.
- Now using the Java install4j wizard to create installation packages.
- Re-coded and extended the CoastWatch Data Analysis Tool to work with the Java API. In addition to its 0.7a version, CDAT now has annotation and navigation capabilities, online help, GeoTIFF output, topography overlays, generic bitmask overlays, overlay groups, support for swath files, and more. CDAT is now an integrated part of the package.
- Modified the cwstatus menus to allow users to connect to a different server.
- Removed the cwrender preview option – it was causing problems with headless operations.

- Updated online documentation in cwstatus and cwmaster.
- Replaced palette and RGB database files with XML versions.
- Added the --template option to cwmath so that users may use an existing variable as a template for the new variable rather than having to specify all of its properties.
- Added an update agent to graphical tools that informs the user if a software update is available.

Version 3.1.8, 2004/11/25

Updates

- Extended data caching in I/O routines to handle arbitrary size data arrays. Previously, some utilities would memory-thrash when faced with a large column count.
- Renamed various SatelliteXXX classes to EarthXXX to mirror more generality in metadata.
- Updated I/O for new metadata specifications, including multiple time periods and composite attributes.
- Modified the default metadata version to 3.2. Now by default, new files created with the utilities are no longer compatible with the older CDAT version 0.7a and earlier.
- Updated coastline data files to GSHHS v1.3 and corrected known polygon fill problems on the US East Coast, Africa, and South America.
- Updated ETOPO5 topography database and corrected problems with contours fills producing strange bullseye artifacts.
- Added a --timeout option to cwdownload to allow the user to select a network timeout value.
- Added a --transform option to cwinfo to print Earth transform information.
- Modified the behaviour of cwcomposite to append dataset metadata together rather than simply use the last file's global metadata (time, satellite, etc). The --pedantic option was also added to allow exact tracking of source dataset metadata.
- Added a --inputs option to cwcomposite to allow the user to specify a list of files in a text file rather than on the command line.
- Recompiled the HDF library for Linux to allow up to 256 open files. This allows the cwcomposite to handle more than 31 input datasets which was the previous limit.
- Modified cwmath to allow multiple input files, and output to an existing file that is not an input file.
- Updated to new install4j installation package wizard to fix various bugs and allow the user to select components during a graphical installation.
- Added various option to cwcoverage tool for plotting ground station coverage circles.

Bug fixes

- Fixed stall problem in cwdownload when data server is unavailable or not responding within a certain timeout period.
- Fixed spelling problems with GCTP sinusoidal projection.
- Fixed swath reverse-lookup problems for non-AVHRR data.
- Fixed registration problems with partially swath-covered partitions in the output dataset.
- Fixed bitmask overlay navigation problem in CDAT.
- Fixed font problems in overlay group loading in CDAT on MacOS X.
- Fixed small polygons bug in CDAT coastline overlay.
- Fixed legend bounding rectangle line style problems in output from CDAT and cwrender.
- Fixed bitmask overlay rendering problems in CDAT on MacOS X.
- Fixed step color scale problems in image file output from CDAT.
- Fixed printing problems in cwinfo and cwstats.
- Fixed CDAT data view size change when many files are opened.
- Fixed CDAT data view so that if multiple file tabs are open and the user switches tabs, the data view does not continue to render to the wrong tab.
- Fixed CDAT problem with allowing multiple overlay property control dialogs.
- Fixed CDAT problem with contour level deletion causing a stall.
- Fixed stall problems in CDAT related to delayed rendering.
- Fixed stall problems in cwstatus when server is not responding.

Version 3.1.9, 2004/04/07

Updates

- Updated NOAA 1b AVHRR reading for version 3 format.
- Added support in metadata and CW HDF reading/writing for sensor scan geometry geostationary satellite data.
- Added LZW compressed GIF output for CDAT and cwrender.
- Added mixed resampling method to cwregister for handling discontinuities in the source data, such as in MODIS sensor data.
- Added cwautonav tool for estimating navigational corrections using image data.

- Added transparent overlay color rendering in CDAT and cwrender, specifically for overlaying user-specified polygon data without obscuring the background image.
- Modified graphical tools to output error messages that would normally go to the terminal to a dialog. Now users will be able to see "uncaught" exceptions and decide to ignore them or file a bug report.
- Added standard palettes specific to chlorophyll data.
- Added basic ESRI shapefile rendering support in CDAT and cwrender.
- Reformatted all tool manual pages and usage notes for clarity, as well as adding the equivalent one-letter options for all word-length options.
- Added general settings section in CDAT user preferences, initially for lat/lon format preferences.
- Modified all tools to clean up partially written data files after unexpected errors have occurred.
- Modified cwexport and cwrender to detect the desired file format based on the output file extension.
- Added --nostates (don't plot state border, just international borders) and --logo (plot a user-specified logo) options to cwrender.
- Added --imagecoords (print image row and column coordinates) to cwsample.
- Added log scale enhancements to CDAT.
- Updated graphical tool icons, menus, help pages, and Unix look-and-feel.
- Modified drop shadow rendering in CDAT and cwrender for better text readability.
- Added --projection option to cwdownload to allow the user to download only mapped or swath data files.

Bug fixes

- Fixed overflow problem when writing HDF attribute data beyond 65535 values long.
- Fixed registration problem with navigationally corrected data.
- Fixed inappropriate missing value problem in ESRI ArcGIS grid and raw float output.
- Fixed "almost equals" problem with map projection parameter comparisons.
- Fixed background fill problem in CDAT data view when performing navigation.
- Fixed CDAT image saving bug; data view changed or became unusable after saving.
- Fixed problem with CDAT leaving files open even when user has closed file.
- Fixed PDF page size problem.

Version 3.2.0, 2005/10/08

Updates

- Added RasterPixelIsPoint style Earth location code for wind data.
- Improved speed of NOAA 1b reading by caching scan lines rather than tiles, as this reflects the actual file organization.
- Added support for OPeNDAP-accessible datasets with CoastWatch HDF metadata.
- Updated to perform datum shifting between Earth transforms of different datums.
- Changed "datum" terminology to "spheroid" in various locations.
- Added support for abstract GIS features to help in ESRI shapefile processing.
- Added spectrum and wind palettes for cwrender and CDAT.
- Added --limits option in cwstats.
- Added check for incompatible overlay group files in CDAT.
- Added support in cwrender for overlay group rendering, world files, vector data rendering, and units conversion.
- Updated CDAT to have a special interface for opening OPeNDAP connections and datasets, moved file information to a full size window, and added 1:1 toolbar button.
- Added various detailed control options in cwautonav.
- Added hdatt tool for direct manipulation of HDF attribute information.

Bug fixes

- Corrected NOAA 1b longitude interpolation in polar regions.
- Modified to ignore coordinate variables in HDF files (for compliance with CF metadata conventions).
- Relaxed NOAA 1b format description check for varying descriptions in CLASS data files.
- Fixed unreliable convergence problem in swath Earth location reverse lookup algorithm.
- Fixed dropouts between rectangles in mixed resampling method for cwregister.
- Fixed Earth context element in output from cwrender to not draw coverage polygon when area is larger than orthographic projection area.
- Fixed problem with minimized window icons in graphical tools.
- Modified cwmaster so that map projections that support only sphere Earth models cannot be saved with an ellipsoid model.
- Modified the default locale for number formatting and printing to English/US to resolve problems with inconsistent parsing of numbers formatted in other countries.

Version 3.2.1, 2006/11/21

Updates

- Updated GUI code for better Mac OS X integration.
- Added help buttons in some areas of CDAT to aid users in getting context-specific help.
- Added color scale legend beside data view in CDAT in response to user suggestions.
- Added warning message in CDAT before applying navigation to make sure user understands that the data file is being modified.
- Changed "Save As" in CDAT to "Export" to avoid confusion. The data file should be thought of as read-only and the save formats as export formats.
- Changed the order of operations for exporting data in CDAT to simplify the number of steps users need to perform.
- Added continuous enhancement updates in CDAT for visual appeal.
- Updated icons for data view controls in CDAT.
- Added drag-and-drop support in CDAT for opening data files.
- Updated all dialog box buttons in CDAT to more closely match platform defaults.
- Factored code for earth transforms to allow for both native C and Java map projection implementations in the future.
- Added support in CDAT and cwrender for expression masking.
- Added support in CDAT for preferred units.
- Added support in CDAT and cwrender for saving image files with indexed 8-bit palettes.
- Added support in CDAT and cwrender for saving world files.
- Changed splash screen to not display by default for GUI tools. This was causing users to think that startup was abnormally slow.
- Added support in NOAA 1b reading code for version 4 and 5 file formats, 8-bit and 16-bit sensor word sizes, MetOp data files, and files with missing scan lines.
- Added support for user file formats via the extensions/ directory.
- Added TIFF file compression in CDAT and cwrender.
- Added code for the Earth Data Access Client (EDAC) for for use by the CoastWatch East Coast Node (ECN).
- Added support in TeraScan HDF I/O code for importing a user-specified set of attributes.
- Updated GSHHS reading code to handle binned political line data, and replaced databases in TeraScan vector format with new HDF binned data from GMT. This speeds up the access and rendering of state and international lines considerably.

- Enhanced color scale in cwrender and CDAT to correctly show log scale ticks above the highest power of ten on the scale. This helps with chlorophyll plotting when users scale between non-power-of-ten minimum and maximum.
- Added CDAT and cwrender palettes for Coral Reef Watch data.
- Added the --coherent option to cwcomposite based on CoastWatch central processing request. See the manual page for details.
- Updated look and content of application help files for CDAT, cwmaster, and cwstatus to be easier to read and navigate.
- Added ubyte/ushort types, and xor/not functions to cwmath.
- Added the --overwrite option to cwregister based on CoastWatch central processing request. See the manual page for details.
- Added the ability in cwrender to accept multiple --shape and --bitmask options. This makes rendering much more flexible.
- Added the --variable option to cwsample. It was confusing to users to have only --match and not be able to depend on the ordering of columns in the output text file.
- Added the --region option to cwstats that takes a center point and radius for sampling.
- Modified the base directory for user preferences to be operating system specific. The base directory was causing problems because different operating systems expect software to place customization directories in different locations. See the help files in CDAT for the new locations.
- Standardized on coastwatch.info@noaa.gov as the destination for all support emails.

Bug fixes

- Fixed error with log enhancement normalization by disabling the Normalize button for log enhancements.
- Fixed status dialog problem in CDAT when loading variables with long names from files with short names.
- Fixed color, stroke, and font swatch rendering in CDAT for Mac OS X.
- Fixed problem with writing ArcGIS files from CDAT and cwexport. Header file accuracy was being impacted by writing to only two decimal places.
- Fixed problem when reading OPeNDAP files with 2D data of odd dimensions.
- Fixed error with retrieving chunks lengths while reading netCDF files, since netCDF has no chunking or compression support.
- Fixed null line color errors in CDAT overlays.
- Fixed problem with rendering text shadows for black grid lines in CDAT and cwrender.

- Fixed problem with lat/lon separator characters in cwautonav. Now the documentation and implementation match.
- Fixed cwdownload to delete partial files when a transfer error occurs.
- Fixed the lack of equation description in log-enhanced GeoTIFF output from cwrender and CDAT.
- Fixed error when working with geographic projection data that crosses the date line.

Bibliography

[1] General Cartographic Transformation Package. http://edcwww.cr.usgs.gov/pub/software/gctpc.

[2] Global Self-consistent, Hierarchical, High-resolution Shoreline Database. http://www.ngdc.noaa.gov/mgg/shorelines/gshhs.html.

[3] Interactive Data Language. http://www.rsinc.com.

[4] Matlab. http://www.mathworks.com.

[5] NCSA HDF. http://hdf.ncsa.uiuc.edu.

[6] Open-source Project for a Network Data Access Protocol (OPeNDAP). http://www.opendap.org.

[7] Unidata UDUNITS package. http://my.unidata.ucar.edu/content/software/udunits/index.html.

[8] *HDF Reference Manual, Version 4.1r2.* University of Illinois at Urbana-Champaign, June 1998.

[9] *HDF User's Guide, Version 4.1r2.* University of Illinois at Urbana-Champaign, June 1998.